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THE LUNAR SURFACE AND ITS TEMPERATURE.

By JOHN ERICSSON.

From "Nature."

A MONOGRAPH by the writer, relating to the temperature of the lunar surface, read before the American Academy of Science, September, 1869, contained the following:

"Are we not forced to dissent from Sir John Herschel's opinion that the heat of the moon's surface, when presented to the sun, much exceeds that of boiling water? Raised to such a high temperature, our satellite, with its feeble attraction, could not possibly be without an envelop of gases of some kind. Indeed, nothing but the assumption of extreme cold offers a satisfactory explanation of the absence of any gaseous envelop round a planetary body, which, on account of its near proximity, cannot vary very much from the earth as regards its composition. The supposition that this neighboring body is devoid of water, dried up and sunburnt, will assuredly prove one of the greatest mistakes ever committed by physicists."

This assertion was based on demonstrations showing that the circular walls of the great "ring mountains" on the lunar surface are not, as supposed, composed of "mineral substances originally in a state of fusion." The height and diameter of these walls being recorded in "Der Mond," computations based on the safe assumption that the areas of their transverse sections cannot be less than the square of their height, establishes the important fact that the contents of the wall of, for instance, Tycho, the circumference of which is 160 miles, height 2.94 miles, amounts $2.94^2 \times 160 = 1382$ cubic miles. The supposed transfer of this enormous mass, in a molten state, a distance of 25 miles from the central vent imagined by Nasmyth, and its exact circular distribution at the stated distance, besides its elevation to a vertical height of nearly 3 miles, involve, I need not point out, numerous physical impossibilities. Other materials and agencies than those supposed to have produced the "ring mountains" must consequently be sought in explanation of their formation. A rigid application of physical and mechanical principles to the solution of the problem proves conclusively that water subjected successively to the action of heat and cold has produced the circular walls of Tycho. The supposition that these stupendous mounds consist of volcanic materials must accordingly be rejected, and the assumption admitted that they are inert glaciers which have become as permanent as granite mountains by the action of perpetual intense cold.

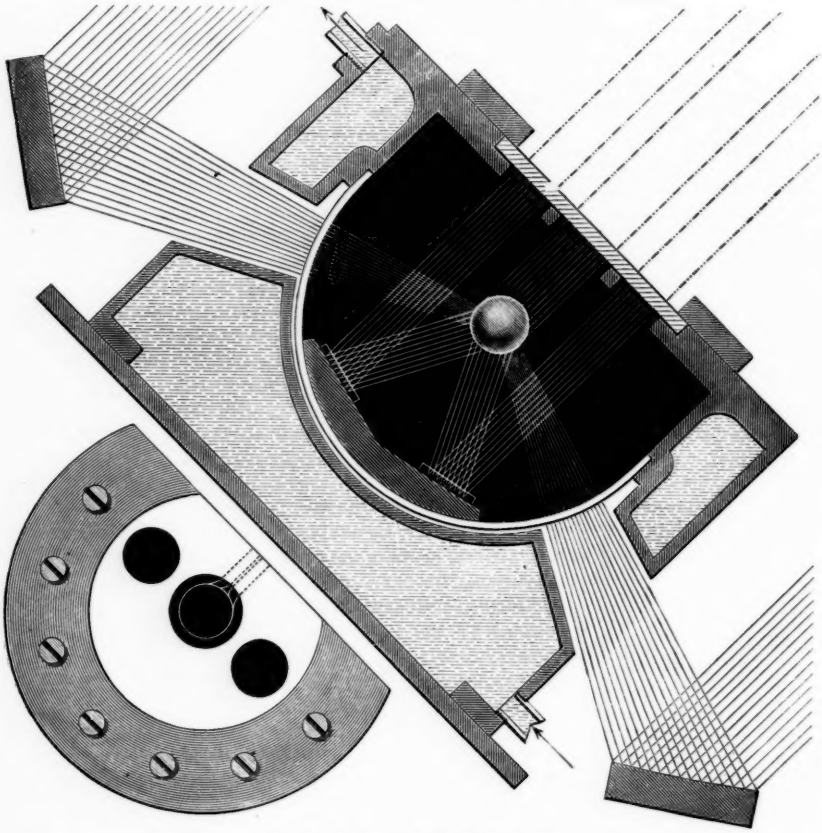
Independently of the foregoing demonstration, the fallacy of the volcanic hypothesis will be comprehended by its advocates on learning that the quantity of lava requisite to form the circular

walls of Tycho would cover the entire surface of England and Wales to a depth of 125 feet.*

Before proceeding further with our demonstration it will be necessary to establish the maximum temperature which solar radiation is capable of imparting to the lunar surface. This temperature, of course, varies with the distance of the primary and its satellite from the sun. By means of an actinometer the bulb of whose thermometer receives an equal amount of radiant heat on opposite sides, I was enabled to determine with desirable accuracy, sixteen years ago, that, when the earth is in aphelion, solar radiation on the ecliptic imparts a maximum temperature of 67°.2 F., and that the retardation of the radiant energy occasioned by the want of perfect atmospheric diathermancy reaches 0.207. Consequently the temperature produced by solar radiation at the boundary of the terrestrial atmosphere is

$$67.2 \times 1.207 = 81°.11 \text{ F.},$$

when the earth is in aphelion. Agreeably to observations during the winter solstice, compared with observations at midsummer, at equal zenith distance, the augmentation of solar intensity when the



Captain Ericsson's Pyrheliometer.

* Area of England and Wales, 58,320 square miles; contents of the walls of Tycho, 1382 cubic miles; hence $\frac{1382}{58320} \times 5280 = 125.12$ feet.

earth is in perihelion amounts to 5°.84 F.; hence the temperature produced by solar radiation reaches

$$81.11+5.84=86°.95 \text{ F.},$$

when the rays enter our atmosphere during the winter solstice. It should be observed that on theoretical grounds the increase of temperature, when the earth is in perihelion, will be in the inverse ratio of the *dispersion of the solar rays*; hence, as the aphelion distance is to the perihelion distance as 218.1 to 210.9, it will be seen that the temperature produced by solar radiation when the earth is in perihelion will be

$$\frac{218.1^2\times 67°.2}{210.9^2} = 71°.86 \text{ F.}$$

Adding 0.207 for retardation caused by imperfect atmospheric diathermancy, solar intensity during the winter solstice will be

$$71.86\times 1.207=86°.73 \text{ F.}$$

Calculation based on *observation*, as before stated, proves that the perihelion temperature is 86°.95, thus showing a trifling discrepancy between theory and observation.

Adopting 86°.73 as correct, it will be found that the yearly *mean* temperature produced by solar radiation when the rays enters the earth's atmosphere will be

$$\frac{81°.11+86°.73}{2}=83°.92 \text{ F.},$$

while the temperature produced by the sun's radiant heat is only 81°.11 during the summer solstice, as before shown. Hence the temperature of the lunar surfece when presented to the sun while the earth is furthest from the luminary can only be augmented 81°.11 F.

The remarkable fact that the moderate heat produced by solar radiation is cap able of increasing the temperature of bodies previously heated to a high degree demands consideration in connection with the subject under investigation; also the nature of the device, before referred to, for ascertaining the temperature produced by solar radiation. The accompanying illustration represents a combination of said device and a pyrheliometer differing materially from Pouillet's instrument, by showing the true intensity of the "fire" in the sun's rays.

The illustration presents a top view and a vertical section of the new instrument through the center line. The upper part, composed of bronze, is cylindrical with a flat top, the bottom being semispherical, composed of ordinary glass. The top of the cylindrical chamber is provided with three circular perforations covered by a thin crystal carefully ground and polished. A thermometer having a spherical bulb is introduced through the side of the chamber, the bulb being central to the transparent semispherical bottom. A short parabolic reflector, shown in section on the illustration, surrounds the instrument, adjusted so that its focus coincides with the center of the bulb of the thermometer. The compound cylindrical and spherical chamber is inclosed in a vessel containing water, appropriate openings at top and bottom being provided for maintaining constant circulation during experiments. Efficient means are also provided for exhausting the air from the internal chamber. The instrument is secured to the top of a substantial table which, during experiments, faces the sun at right angles by the intervention of a parallactic mechanism. Movable shades are applied, by means of which the sun's rays may be quickly cut off from, or admitted to, the parabolic reflector; while other shades enable the operator to admit or exclude the solar rays from the circular perforations at the top of the exhausted chamber. It will be readily understood that the parallel lines within the exhausted chamber, shown on the illustration, indicate the course of the solar rays passing through the crystal and the perforations at the top, while the converging radial lines indicate the rays reflected by the parabolic reflector. The upper hemisphere of the thermometric bulb, it will be seen, receives the radiant energy of the sun's rays which pass through the large central perforation; while the lower half of the bulb will be acted upon by the rays passing through the small perforations. These rays are reflected upwards by two inclined circular mirrors attached to the bottom of the exhausted chamber. It should be particularly observed that the areas of these inclined mirrors *together* should exceed the area of the great circle of the

bulb of the thermometer sufficiently to make good the loss of radiant energy caused by the imperfect reflection of the said mirrors, and also to make good the loss attending the passage of the solar rays through the crystal. A capacious water cistern, connected by flexible tubes with the external casing of the pyrheliometer, enables the operator to maintain the exhausted chamber at any desirable temperature. Engineers of great experience in the application of heat for the production of motive power and other purposes deny that the temperature of a body can be increased by the application of heat of a lower degree than that of the body whose temperature we desire to augment. The soundness of their reasoning is apparently incontrovertible, yet the temperature of the mercury in the instrument just described raised to 600° F. by means of the parabolic reflector, increases at once when solar heat is admitted through the circular apertures, although the sun's radiant intensity at the time may not reach one-tenth of the stated temperature. It should be mentioned that the trial of this new pyrheliometer has not been concluded, owing to very unfavorable atmospheric conditions since its completion. For our present purpose the great fact established by the illustrated instrument is sufficient, namely that the previous temperature of a body exposed to the sun's radiant heat is immaterial. The augmentation of temperature resulting from exposure to the sun, the pyrheliometer shows, depends upon the intensity of the sun's rays.

Regarding the temperature prevailing during the lunar night, its exact degree is not of vital importance in establishing the glacial hypothesis, since the periodical increment of temperature produced by solar radiation is only a fraction of the permanent loss attending the continuous radiation against space resulting from the absence of a lunar atmosphere; besides, all physicists admit that it is extremely low. Sir John Herschel says of the night temperature of the moon that it is "the keenest severity of frost, far exceeding that of our Polar winters." Proctor says: "A cold far exceeding the intensest ever produced in terrestrial experiments must exist over the whole of the unilluminated hemisphere." The author of "Outlines of Astronomy" has also shown that the temperature of space, against which the moon at all times radiates, is −151° C. (−239°.8 F.), Pouillet's estimate being −142° C. (−223°.6 F.). Adopting the latter degree, and allowing 81°.11 for the sun's radiant heat, we establish the fact that the temperature of the lunar surface presented to the sun will be 223°.6 less 81.°1, or −142°.5 F., when the earth is in aphelion. It will be well to bear in mind that when the earth is in the said position, the sun's rays acting on the moon subtend an angle of 31′ 32″, hence the loss of heat by radiation against space will be diminished only 0.000021 during sunshine. Nor should Herschel's investigation be lost sight of, showing that stellar heat bears the same proportion to solar heat as stellar light to solar light. Stellar heat being thus practically inappreciable, the temperature produced by stellar radiation cannot be far from absolute zero—an assumption in harmony with the views of those who have studied the subject of stellar radiation, and consequently regard Pouillet's and Herschel's estimate of the temperature of space as being much too high.

Having disposed of the question of temperature, let us return to the practical consideration of the glacial hypothesis. The formation of annular glaciers by the joint agency of water and the internal heat of a planetary body devoid of an atmosphere and subjected to extreme cold is readily explained on physical principles. Suppose a sheet of water, or pond, on the moon's surface, covering the same area as the plateau of Tycho, viz., 50 miles diameter and 1960 square miles. Suppose, also, that the internal heat of the moon is capable of maintaining a moderate steam pressure, say 2 lbs. to the square inch, at the surface of the water in the pond. The attraction of the lunar mass being only one-sixth of terrestrial attraction, while the moon's surface is freed from any atmospheric pressure, it will be evident that under the foregoing conditions a very powerful ebullition and rapid evaporation will take place, and that a dense column of vapor will rise to a considerable height above the boiling water. It will also be evident that the expansive force within this column at the surface of the water will be so powerful at the stated pressure that

the vapor will be forced beyond the confines of the pond in all directions with great velocity. No vertical current, it should be understood, will be produced, since the altitude of the column, after having adjusted itself to the pressure corresponding with the surface temperature of the water, remains stationary, excepting the movement consequent on condensation from above. The particles of vapor forced beyond the confines of the pond, on being exposed to the surrounding cold, caused by unobstructed radiation against space, will of course crystallise rapidly, and in the form of snow fall in equal quantity round the pond, and thereby build up an annular glacier. As the radius of the vaporous column exceeds 25 miles, it will be perceived that, notwithstanding the rapid outward movement, before referred to, some of the snow formed by the vapors rising from the boiling pond will fall into the same, to be melted and re-evaporated.

In connection with the foregoing explanation of the formation of annular glaciers, their exact circular form demands special consideration. An examination of Rutherford's large photograph of the lunar surface shows that, apart from the circular form of the walls, the bottoms of the depressions are in numerous cases smooth, rising slightly towards the center uniformly all round. The precision observable proves clearly the action of formative power of great magnitude. Referring to what has already been explained regarding the vaporous column of 25 miles radius, calculation shows that a surface temperature exerting the moderate pressure of 2 lbs. to the square inch will produce an amount of mechanical energy almost incalculable. Practical engineers are aware that the steam rising from a surface of water 10 square feet, heated by a very slow fire, is capable of producing an energy of 1 horse-power; consequently a single square mile of the boiling pond will develop 2,780,000 horse-power. This prodigious energy will obviously be exerted *horizontally*, as the weight of the superincumbent column of vapor balances its *expansive* force precisely as the weight of our atmosphere balances its expansive force. But unlike the earth's atmosphere, which is re strained from horizontal movement by its continuance round the globe, the vapor of the column of 50 miles diameter is free to move beyond the confines of the pond. A very powerful horizontal motion, especially of the lower part of the vaporous mass, will thus be promoted, acting in radial lines from the center, the principal resistance encountered being the friction against the water. Considering that the friction against the surface of the ocean, caused by the gentle trade-wind, is sufficient to produce the Gulf Stream, we need no figures to show the effect on the water in the boiling pond produced by the vaporous mass propelled by an energy of 2 lbs. to the square inch, in radial lines towards its confines. A circular tidal wave of extraordinary power, together with a return under-current towards the center, will obviously be the result. But agreeably to the laws supposed to govern vortex motion, these currents cannot be maintained in a radial direction. A rotary motion, rapidly augmenting, will take place, producing a vortex more powerful than any imagined by Descartes. The radial currents of the vaporous column having assumed a spiral course, will rapidly acquire a velocity exceeding that of a cyclone. The practical effect of the powerful movement of the vortex, it is reasonable to suppose, will resemble that of a gigantic carving-tool whose thorough efficiency in removing irregularities has been proved by the exact circular outline presented by thousands of lunar formations. The terraces within the "ring mountains" indicated on Beer and Mädler's chart, it may be shown, were produced by evaporation resulting from low temperature and reduced energy after the formation of the main glacier.

There is another feature in the lunar landscape scarcely less remarkable than its circular walls and depressions. In the center of nearly all of the latter one or more conical hills rise, in some cases several thousand feet high. Has the rotary motion of the boiling vortex any connection with these central cones? A brief explanation will show that the connection is quite intimate. The underrated estimate that 10 square feet of surface under the action of slow fire is capable of developing one horse-power proves the presence of a dynamic energy exceeding 5,000,000,000 of horse-power

at the base of the vaporous column resting on the boiling water of a pond as large as that of Tycho. No part of this power can be exerted vertically, as already explained, on the ground that the weight of the vapor restrains such movement. The great velocity of the vortex resulting from the expenditure of the stated amount of dynamic energy will of course produce corresponding centrifugal force; hence a maelström will be formed capable of draining the central part of the pond, leaving the same dry, unless the water be very deep, in which case the appearance of a dry bottom will be postponed until a certain quantity of water has been transferred to the glacier. It should be observed that the central part of the bottom, freed from water, will also be freed from the surrounding cold by the protection afforded by the vaporous mass. The quantity of snow formed above the center, at great altitude, will be small, and of course diverged during the fall. Evidently the dry central part, prevented, as shown, from cooling, will soon acquire a high temperature, admitting the formation of a vent for the expulsion of lava, called for as the moon, whose entire dry surface is radiating against space, shrinks rapidly under the forced refrigeration attending glacier-formation. Lava-cones similar to those of terrestrial volcanoes, and central to the circular walls, may thus be formed, the process being favored by the feebleness of the moon's attraction. The existence of warm springs on the protected central plains is very probable; hence the formation of cones of ice might take place during the last stages of glacier-formation, when those plains no longer receive adequate protection against cold.

In accordance with the views expressed in the monograph read before the American Academy of Science, continued research has confirmed my supposition that the water on the moon bears the same proportion to its mass as the water of the oceans to the terrestrial mass. I have consequently calculated the contents of the circular walls of the "ring mountains" measured and delineated by Beer and Mädler, and find that these walls contain 630,000 cubic miles. The opposite hemisphere of the moon being subjected to similar vicissitudes of heat and cold as the one presented to the earth, the contents of the circular walls not seen cannot vary very much from those recorded in "Der Mond"; hence the total will amount to 1,260,000 cubic miles. Allowing for the difference of specific gravity of ice, the stated amount represents 1,159,000 cubic miles of water. But "Der Mond" does not record any of the minor circular walls which, as shown by the large photograph before referred to, cover the entire surface of some parts of the moon. On careful comparison it will be found that the contents of the omitted circular formations is so great that an addition of 50 per cent. to the before-stated amount is called for. An addition of 25 per cent. for the ice-fields, whose extent is indicated by cracks and optical phenomena, is likewise proper. The sum total of water on the moon, therefore, amounts to 2,028,600 cubic miles.

Adopting Herschel's estimate of the moon's comparative mass, viz. 0.01 1364, and assuming that the oceans of the earth cover 130,000,000 square miles, it will be seen that the estimated quantity of water on the moon corresponds with a mean depth of 7,250 feet of the terrestrial oceans.* This depth agrees very nearly with the oceanic mean depth established by the soundings for the original Atlantic cable, viz. 7,500 feet; but the result of the Challenger Expedition points to a much greater depth. This circumstance is by no means conclusive against the supposition that the satellite and the primary are covered with water in relatively equal quantities. The correctness of Sir John Herschel's demonstration proving the original tendency of the water on the lunar surface to flow to the hemisphere furthest from the earth must be disproved before we reject the assumption that the quantity of water on the surface of the moon bears the same proportion to its mass as the quantity of water on the earth to the terrestrial mass.

* $\frac{2028600 \times 5280}{130000000 \times 0.011364} = 7{,}250$ feet mean depth of terrestrial oceans corresponding with water on the moon.

MESSRS. P. AND W. M'LELLAN, of Glasgow, have obtained the contract to supply the steel work of ten bridges, four of which are to be 100 ft. span, and six 75 ft., for the Midland Railway of India.

PERFORMANCE OF STEAM ENGINES.

By GEO. H. BARRUS.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE

My attention was some time ago called to the article in the February number of your magazine, written by Mr. John W. Hill on "Performance of Steam Engines" but I have not, until now, owing to pressure of business, had the opportunity which I wished to express my disapproval of the writer's conclusions. The subject is such an important one, and Mr. Hill's conclusions appear to be so erroneous and so liable to mislead those who are unfamiliar with steam engineering, and it may be also those even who are familiar with the subject, that I beg the liberty of criticising the article.

Mr. Hill states that he has made many experiments on first class engines, and has come to the conclusion that "for engines operating at piston speeds of 100 to 400 ft. per min. compounding will be found beneficial; but for high piston speeds of 600 or more feet, the single cylinder can be made to furnish the best economy," and he makes the proviso that "no benefit will be found in compounding for an engine working at six or less expansions." He seeks to exemplify these conclusions by quoting from the results of tests which he made on E. P. Allis & Co's compound engine at the Daisy Mill in Milwaukee, Wis., and a Harris-Corliss single cylinder engine of the common type, the location of which is not given, but which I understand is at the flour mill of A. A. Freeman & Co., La Crosse, Wis.

I have little to say in regard to Mr. Hill's conclusions, except to state that they do not appear to be sound. What I have to say refers to the propriety of basing such conclusions upon the results of the tests that are quoted.

I would call attention to the following table which gives the essential points in the data and results of the tests that bear upon the question:

Kind of Engine.	Compound.	Simple.
Size of cylinder.....in.	1 14×42 1 26×42	1 24×60
Nominal power of eng. H.P.	160.	275.
Indicated horse power developed..... I.H.P.	120.6	270.6
Kind of Boilers Supplying Steam.	Babcock & Wilcox.	Horizontal Return Tubular, fitted with domes, and above the domes a steam drum.
1. Proportion of stroke completed at cut-off.....	H P.Cyl. .198	.156
2. Ratio of expansion by volumes.....	23.4	5.5
3. Feed water consumed by engine per indicated horse power per hour (including entrained water in the steam).....lbs.	17.22	18.58
4. Percentage of feed water which enters the engine in the form of entrained water.....per cent.	6.3	13.0
5. Steam accounted for by indicators per I.H.P. per hour (not stated whether at cut-off or release but presumably at release).lbs.	12.28	13.03
6. Proportion of feed water accounted for by indicators (including entrained water)	.713	.701
7. Feed water consumed by engine per indicated horse power per hr. (not including entrained water...lbs.	16.14	16.16
8. Proportion of quantity given in line 7 accounted for by indicators,.....	.761	.807
9. Initial pressure in cylinder.....lbs.	90.7	89.4
10. Revolutions per minute.	76.	59.6
11. Piston speed. ft. per min.	532.	596.

1. It will be noticed, first, that the two engines are quite dissimilar in size. The cylinder of the simple engine is nearly as

large in diameter as the large cylinder of the compound engine. Just what sizes of cylinder should be used in making a thoroughly fair comparison is a matter which is open to question. But there is no question that the compound engine should be at least equal in power to the simple engine. Here the simple engine is some 70 per cent. greater in capacity. Second, it will be noticed that the compound engine was loaded far below its nominal capacity, while the simple engine carried practically its full load. Mr. Hill recognized the fact that the compound engine was unfavorably loaded in his statement that the load was too light for maximum economy, and an ineffectual effort was made to bring it up to the required point, by the use of a friction brake. He does not, however, appreciate fully the great loss induced by a light load in the case of compound engines, for he simply says that with a proper load, "the economy would have been quite as good."

These are two strong reasons why the results of the tests cannot be fairly compared to show the relative economy of compound and simple engines.

2. It will be seen that the compound engine was supplied with steam generated by water tube boilers with no steam drum (presumably), while the simple engine was supplied from fire tube boilers having not only a steam drum, but steam domes as well. It is frequently stated by advocates of fire tube boilers, that these two types of boiler produce steam of unlike degrees of dryness. Whether this is true or not, it seems to me that the prevalence of a feeling indicated by such statements would deter one from comparing engines that were supplied by these boilers. If this, however is not a sufficient objection to the comparison, the fact that unusual precautions were taken to secure dry steam, as was evidently done in the case of one of the plants, would seem to put a comparison altogether out of the question.

3. The results of the calorimeter tests as recorded bear me out in the claim that no fair comparison between the engines can be made, being supplied as they are with steam from two different boilers. The difference in the quality of the steam in the two cases is exceedingly marked. The Babcock & Wilcox boilers gave 6.3 per cent. of moisture, while the tubular boilers, in spite of the special arrangement of the plant which has been noted made with a view to produce dry steam, gave 13 per cent. of moisture! In passing, let me here encourage the advocates of water tube boilers to pursue their efforts. If there were no prospect before of their getting dry steam there is now good grounds for the hope that some day they may realize their expectations. In spite of domes and steam drums, it seems that the shell boiler still gives steam which is one-eighth water, while the water tube boiler has got the figure down to 6.3 per cent. With these facts staring at him, Mr. Hill will surely become the champion of water-tube boilers! Until these figures came to notice, I had supposed that engine economy and dry steam went hand in hand, but it seems that an engine can be supplied with steam containing as much as 13 per cent. of moisture, and still be the most economical engine on record!

4. Looking at the matter seriously, and taking the figures as they stand, it is altogether unreasonable to compare the performance of two engines, the steam for one of which contains 6.7 per cent. more moisture than the steam for the other. It is not fair to make such a comparison, even though the so-called "entrained water" is deducted from the gross amount used. I have experimental data which point to the probability that the presence of moisture in the steam leads to the formation in the cylinder of a much larger quantity of cylinder condensation, than would otherwise occur. The waste due to wet steam does not stop at the throttle valve, but follows through the cylinder and continually increases during its passage. If this had been taken into account by Mr. Hill, the comparison which he has made would result even more favorably to the simple engine than his figures have made it appear.

5. The reasons thus far given are quite sufficient to show that the tests are of no use whatever for making a fair comparison of simple and compound engines, but there is a still stronger reason not yet named.

Mr. Hill bases his figures of comparison on the amounts of feed water consumed by the engines, not including

the "entrained water" in the steam. The amount of entrained water is determined in each case by calorimetric tests. He really bases the comparison, then, on the indications which the calorimeter reveals of the state of humidity of the steam. I have no knowledge either of the type of calorimeter used, or of the method of conducting the trials. I have some knowledge however, of the general subject of calorimetric tests, a sufficient amount, at least, to be thoroughly aware of the delicate nature of those tests, if conducted with proper apparatus, and with sufficient care to insure reliable results. Although having no knowledge of these particular tests, I venture the assertion that they are wholly erroneous. The results of the engine tests, on the face of them, bespeak their inaccuracy. The reasons for this assertion are as follows: First the largest amount of moisture which I have ever obtained by calorimetric test of any boiler whatever, whether fire tube or water tube, is 3 per cent. Second, the largest proportion of feed water accounted for by the indicator that I have obtained from simple engines running under the conditions of the one tested by Mr. Hill, is 0.73, even in cases where the calorimetric test showed but 1 per cent. of moisture and the valves and piston of the engine were tight. I do not wish to be understood that I think it impossible for steam to contain so much moisture as the amounts given in Mr. Hill's article, but I do think it is impossible for a Corliss engine to develop an indicated horse power with a consumption of 18.58 lbs. of steam per hour, when that steam contains 13 per cent. of moisture, as was purported to have been done in the case in question.

If Mr. Hill has no stronger fabric out of which to frame a theory of the relative economy of simple and compound engines than that furnished by the examples given in his article, his opinion is not based on that careful attention to the matter which the importance of the subject and a due consideration of its merits demand.

THE LIMIT OF SPEED IN OCEAN TRAVEL.

By F. M. F. CAZIN.

Written for Van Nostrand's Engineering Magazine.

Prof. R. H. Thurston's article on the limit of speed in ocean travel, reproduced in the June issue of this journal, serves as an occasion for the publication of this polemical essay, but it is not the original cause thereof. I admit that, in assailing the views, as Prof. Thurston has expressed them, I assail all present and traditional teaching concerning the dynamical relations between the immersed solid and the immerging or submerging medium. I realize that I should plead for indulgence in so doing. I therefore do first state that in so bold a challenge I consider it to be fortunate to meet an adversary on the field of scientific strife of so high standing and well-deserved renown as Prof. R. H. Thurston.

In dynamics those learned in the matter have acquiesced in a case of precedents, while it so happened that the case to which the precedent has been habitually and traditionally applied is not analogous to the precedent.

Not Weissbach and Rankine alone, but all their preceding and succeeding writers on mechanics and dynamics have laid the foundation for their teaching concerning the dynamical relations now under consideration by stating the experimental and theoretical results obtained, when a jet of water projected from an orifice strikes a resisting solid face. The formula for the effect thus obtained as $S=\frac{v^2}{2g}$ has had a general universal and exclusive effect on all the teachings referred to.

At another place and at an earlier date, when discussing in publication this point of inapplicability with an equally learned adversary, I believe to have properly shown such to exist. It may, at this place, suffice to state that the value g

is inapplicable in the premises, both solid and medium being subject to gravitation absolutely and in common, and not the one as against the other.

But it is not this negative side of the question which it is proposed to discuss at present. It is at present my intention to be positive in showing that the questions, which Professor Thurston says admit of no definite answer, do indeed admit of such definite answer. But I also desire to precisely state, that unless the present teaching in dynamics, which I consider as a conglomerate of error and truth, caused by connecting cases not bound in analogism—be abandoned—such desirable definite answer cannot be made.

While in order to find the answer desired I have to find a new road of my own, I should not neglect to also show, that not only are more definite answers to be given, but that even those answers, definitely given by Prof. Thurston, suffer under the influence of the erroneous, incomplete and confused present teachings in dynamics, and are incorrect in consequence, and neither more nor less than popular fallacies.

In Prof. Thurston's essay there occur the following propositions, which I provide with numbers for the sake of reference, and with signs for values for the sake of more easy repetition.

(1) The resistance of a steamship or other vessel (=R) consists of two principal points:

(*a*) "The effort required to overcome the friction (=F) of the water on its wetted surfaces.

(*b*) "The force expended in producing the waves (=U) that are seen arising about every ship in motion.*

And the same author further states:

(2) "The friction of hull (=F) is found to be very nearly proportional to the area of wetted surface (=Sf).

(3) "The nearer the form of the ship approaches that of a hemisphere the less must be the resistance due to friction, and between the latter shape and that elongated . . . form which gives minimum *head resistance* there must be some intermediate form which will give the least total resistance.

(4) "The power (=P) demanded to propel any vessel at ordinary speed varies as the square of her length (=d^2) nearly, or as the area of the transverse major section (=MS) and as the cube of the speed (v^3).

(5) "Two vessels being of equal speed (v) and similar form, but the one of twice the length (=d) of the other, the second will require four times the power of the first. The second vessel, however, carries eight times as much weight, and the power per ton of vessel is one half as much as would be demanded by the first, if driven at the higher speed.

(6) "For vessels loaded to a limit with machinery, the higher the speed demanded the larger must be the ship."

When dealing with mechanical problems all expressions used in any statement made must be assumed to have only one plain meaning; this is the one meaning as apparent from the common usage of words, and it is not to be tolerated that in writings on such problems or subjects ambiguity cover up a lack of full understanding. Nor is it admissible that interpretation, becoming possible only consequent to ambiguity of expression, be considered as genuine.

I shall therefore not undertake to find more in the propositions as stated, but what is evident and plain on their face without searching for more therein but what they evidently intended. But distinction must be made between ambiguity on the one side and a well defined new use of and for words on the other.

When expressing new ideas we find a necessity for using new words or for imparting to old words a new meaning.

So I shall have to introduce a new combination of words as: "Transverse average section." I further find the necessity for introducing a new distinction as between the value representing the

* Official Publications of the Royal School of Naval Architecture and Marine Engineering (1873, page 92 of *Annual*) substitute this "*force expended in producing waves*," by "*direct head resistance*," and then divi e this resistance up into such caused by viscosity of water and such caused by the production of waves. The total treatment vividly reminds us of Goethe's Mephistophelic expression: Wo die Begriffe fehlen, Stellt stets zur rechten Zeit ein Wort sich ein.

volume and substance displaced by initial immersion (or submersion) and the value representing the volume and substance of liquid (or fluid) medium displaced by relative motion of solid and medium.

The substance displaced by the immersion of ship bottom equal in weight to the ship's total weight is the value which causes its buoyancy, and I therefore propose to express this value by "Buoyance" (=B), while I propose to properly henceforth use the expression "Displacement" (=D) for a total volume displaced of the medium by the solid in relative motion, it being immaterial whether the one or other be in stability as a total relative to third objects.

With the assistance of this new terminology I may proceed to the revision of Mr. Thurston's propositions.

Mr. Thurston's proposition may be correctly rendered by

(1) $$R = F + U.$$

(2) $$F = Sf$$

(4 & 5) $$P^{(1)} : P^{(11)} = d^{(1)3} : d^{(11)2} = MS^{(1)} : MS^{(11)} = v^{(1)3} : v^{(11)3}.$$

To express in mathematical values his propositions (3) and (6) I have attempted in vain on account of the ambiguity. It is for this reason alone that they cannot be considered as precise or correct, others not being considered.

In the first proposition again the value U is so loosely taken, is so absolutely indefinable that it almost excludes itself from discussion. The production of waves (=U) is evidently an effect of relative motion not conditional thereto. Waves are evidence for a waste of power and not a method for applying power or for its useful application. They are certainly not the effect by which to measure the resistance. If thus I am under necessity to treat part of the propositions as invulnerable, because they are of too misty a nature to admit of handling at all, I find enough in what is left to prove the incorrectness of what answers Prof. Thurston gave to his own question, and definite answers where he thinks the questions admit of none.

Coulomb, Rennie and Morin established the since then acknowledged facts that

(*a*) Friction rates as the weight of one substance effective on the other.

(*b*) With smooth faces friction does not increase at the ratio of surfaces being in contact.

(*c*) Friction does not rate with velocity.

The fact (*b*), discussed and admitted since 1853 by the French Academy of Science, makes Prof. Thurston's proposition (2) appear as a fallacy.

(3) In the case of ocean going vessels, friction rates with their weight and not with their surface, it rates with the values B and D, and is therefore no independent coefficient, no factor in the premises at all. But when admitted parallel with and as an effect of weight it becomes for smooth faces only an insignificant coefficient,* when compared with the sole one by which indeed the resistance to relative motion can be valuated. Beaufoy found the cohesive action on wetted smooth solid surfaces to act as an increase of the effect of weight in relative motion to amount to 0.32 kg. per square meter.

Proceeding to Prof. Thurston's third proposition, I find that he establishes the hemisphere as a standard form for comparing others therewith, or to serve as the first form of B to be considered. I beg leave to more closely accommodate to mathematical precedent in selecting the cube $=1^3$ as standard form for comparison, because our arithmetical and stereometrical system admits of no other, all values relating thereto and not to the sphere. As first power for this cube I then select the sole dimension for length used, also by Prof. Thurston, assuming that it be his intention, though not stated, to exclusively speak of effective length or of the length on the waterline, for which length I have selected the expression $=d$.

The form of vessel first referred to in

* How long time it takes for new results in scientific research to reach even those most interested in these results is well illustrated in the matter of friction. The *Annual* of the Royal School of Naval Architecture and Marine Engineering for 1873, in an article "Comparative *Resistances* of Ships, etc.," has the following:

The resistance opposing the motion of any vessel is of two kinds—surface friction, and *what is commonly called direct head resistance.* The same article states as experimental result; "the resistance from friction is less per foot of length for a long surface than for a short one." With all this the results of scientific research on the subject made by the three French scientists forty years earlier, were then unknown at the English Royal Naval School, as they at present were to Prof. Thurston.

proposition (3) can as to its volume then be correctly expressed by:

$$B = d^3 \times \frac{\pi}{6} \times \tfrac{1}{2}.$$

I then may be permitted to generalize the value $\frac{\pi}{6} \times \frac{1}{2}$, so as to render it applicable to all cases and to all forms of vessels, or to all values for B, and to do so by calling this value the *ratio of the volume of the immersed part of vessel to the cube of its length* (=R.*o*.V.) Then I have a general valuation for all vessels without exception in

$$B = d^3 \times \text{R.}o\text{.V.}$$

Or, we may express this same value in a more plastic manner and method by writing it as

$$B = d^3 \times (d \times \text{R.}o\text{.V.})$$

This applied again to the hemisphere [compare proposition (3)] would read:

$$B = d^3 \times \frac{0.5236}{2} d.$$

When comparing the spherical form with other forms d^3 constitutes the transverse section and $\frac{0.5236}{2} d$, the length of a body being in volume an equivalent of the hemisphere, or $\frac{0.5236}{2}$ represents a coefficient to the section d^3, the two representing the value as "*Transverse average section*" of an equal volume of uniform transverse section having d as length.

Having thus prepared a basis for comparison of different forms for the same volume, I may proceed to test propositions (3 and 4) on their merit. Proposition (3) speaks of the *resistance* to motion (=R), proposition (4) of the power demanded to propel (=P). As the power to propel required (=P) does not depend on qualities of the vessel alone, but depends also on the modus of applying such power as against the resisting medium, and further on the qualities and conditions of the resisting medium, it is absolutely impossible to measure the value P by the qualities of the vessel alone, as Prof. Thurston attempts it in his fourth proposition. But the *resistance* to motion (=R) of vessels of all shapes, in all relative positions and at all velocities imaginable may be measured, rated and compared by qualities exclusively of these vessels themselves.

Therefore, when Prof. Thurston rates the value P exclusively on qualities of the vessel he commits an error. But if we were to substitute the value for resistance (R) for the value for "propelling power required" P, even then would proposition (4) not hold good, which, expressed in typical values, would read:

$$P \text{ or } R = d^3 = MS.$$

Now MS, in the case referred to, is as

$$MS = \frac{\pi}{4} \times \tfrac{1}{2} = 0.3927$$

and $d^3 = 2$

As true it is, that $2 > 0.3927$,

as true it is that the propelling power cannot be measured by the square of the vessel's length, and also by the area of her transverse major section.

Knowing already either one or the other of Mr. Thurston's propositions (4) to be false, it may further be shown, that both are fallacies, even when reducing the value P to the value R as exclusively rational in the premises.

And it may also be proven that

$$R = d^3 \times \text{R.}o\text{.V.}$$

be correct for all cases of motion of immersed or submerged solids relative to fluids (water, air), and for bodies (vessels) of all forms and under all variations of relative position of the given form to the direction of motion, as long as it be properly understood:

(*a*) That d is in all cases the length (axis) in the direction of relative motion.

(*b*) That such part of the fluid as remains comparatively stationary with the solid as a consequence of the form of the solid and of the cohesion proper of the fluid, must be considered in all dynamical relations as a supplementary volume to that of the solid.

To express the proposition

$$R = d^3 \times \text{R.}o\text{.V.}$$

in words, the reading would be as follows:

"The resistance offered by an immersed (or submerged) solid (vessel) to relative motion as against the liquid (or fluid) (immersing or submerging) varies for all forms and relative positions as the *transverse average section*, or as the section of an ideal solid, to which the length of

the given solid *in the direction of relative motion* is the length ($=d$), the ideal solid having a uniform transverse section, and the volume of both being equal."

"And such resistance is neither represented by the transverse major section nor by the square of the solid's constructive length."

I may then be permitted to render proof for such thesis.

As I undertake to overthrow traditional and so far uncontradicted propositions in dynamics, there is a resulting necessity to return to the most elementary class of proof for what new thesis I propose. I therefore may be pardoned for the use of such elementary method.

Only by returning to the very simplest of given conditions is it possible to overthrow errors, set up by time and tradition as invulnerable dicta, having assumed almost the general acknowledgment as if they were axioms.

I propose to make use of a burette having a transverse section and bottom $=1^2$, and to fill it with water of a density $=1$ to an elevation of $10-0.5236$. And I propose to use a solid sphere with a diameter$=1$ and a consequent volume

$$=1^3\times\frac{\pi}{6}=0.5236.$$

and also of a density$=1$.

Carefully avoiding all effect of fall, as foreign to the problem underhand, which concerns only the measurement of displaced volumes, I immerse the described sphere in the described column of water.

From the conditions, as stated, it will then be found to have resulted, that the buoyancy of the sphere is attained at the point of its total immersion. But its total immersion will occur at a point 0.5236 higher than the elevation at which the column of water stood previous to the immersion. And the elevation of the total column of water and sphere therein submersed will be

$$=10-0.5236+0.5236=10.$$

And the upper 1^3 of the column will then consist of $1^3\times 0.5236$ solid $+\ 1^3\times 0.4764$ liquid.

It is on the basis of the conditions as thus given that I shall consider the further effect of relative motion of solid and liquid.

Be it assumed that the solid sphere after being fully immersed shall descend in this column of a uniform transverse section $=1^2$, and of an elevation$=10$ for a distance$=1$, equal to its own diameter (in this case$=d$, or as the length in the direction of motion). While at the start of this later motion and under an assumed elevation of 10, the upper 1^3 consisted of $1^3\times 0.5236$ solid$+0.4764$ liquid, and the 2d 1^3 thus consisted exclusively of liquid in volume as 1^3, subsequent to the fall for a distance$=1$, the upper or 1st 1^3 will consist of all liquid, an addition thereto having been made for $+0.5236$ of liquid, which same portion has been raised from the 2d 1^3 to the 1st 1^3. Expressed in words this fact would be read:

"By a fall in submersion for the distance of its own length measured in the direction of motion, a solid raises a volume of the liquid equal to its own volume for the distance of its own length measured in the direction of fall."

Would I use in place of the burette a horizontal trough measuring $1^2\times 10$, and filled with water in volume equal to $(1^2\times 10)-0.5236$, and immerse therein the sphere of a diameter$=1$, thus filling the trough, and if then I would move the sphere horizontally the effect would then be a horizontal displacement of the same character and value in place of a vertical displacement in the previous case.

And then the result may be expressed by:

"The motion of a solid in immersion for once its own length, measured in the direction of relative motion displaces a volume of the liquid being equal to the solid's own volume."

For want of space I must desist from further demonstration of the absolute and general correctness of this proposition, but must leave it to critical readers to ascertain the fact for themselves. The proposition is true for all dynamical relations as between solids immersed and immersing fluid.

I shall draw attention only to one useful conclusion to be drawn from this proposition amongst many it will permit, one relating immediately to the subject under hand. And the conclusion thus drawn represents a definite answer in itself to one of the questions, according to Prof. Thurston, admitting of none.

An ocean steamer measuring on the water line a length=800 feet=$\frac{800}{3.28}$ =243.9 meters weighing and displacing in initial immersion 38,000 tons, or per meter of immersed length $\frac{38,000}{243.9}$=155.8 tons, does move from its front to its keel per meter of travel 155.8 tons of water.

If such steamer shall travel 2,000 meters, with a speed of about a nautical mile in every three minutes, or twenty miles an hour, then its pumping capacity should be $\frac{2000}{3}\times 158.8$ tons = $103.866\frac{2}{3}$ tons or cubic meters of water per minute, when no power is wasted in creating waves. And the horizontal column of water having the length of travel to be moved for the distance of the immersed length of the ship will have a uniform transverse section=155.8 square meters.

The raising of this quantity of water for 1 foot in one minute would demand 6.295 theoretical horse-power. If the assumption of Prof. Thurston be correct, that such a ship would require for the production of approximating such speed 35,000 horse-power, then the horizontal removal from front to stern for a distance of 800' must be equivalent to the raising thereof $\frac{35,000}{6,295}$=5.56 feet high, which it need not be under proper method for removal on the proper line of motion.

Having thus demonstrated the labor performable by each steamer under given conditions, I may proceed to answer the question of shape in as definite a manner.

In my elementary experiment I have demonstrated with a shape of volume having, as ships have a non-uniform transverse section, or with a transverse major section of $=\frac{\pi}{4}$.

But a cylinder of equal length=d=1 having a uniform transverse section AS=$\frac{\pi}{6}$, being in this as in all cases by volume=$d^3\times$R.o.V. as AS=$d^2\times$R.o.V.=$1^2\times 1\frac{\pi}{6}$ possesses an equal volume with the sphere considered, d being=1 for both.

But AS : MS=2 : 3.

If these two different forms for the same volume are treated as I have treated the sphere all the effects of motion and displacement obtainable and perceptible from the remaining result are identical. The transverse average section is in common to both, the major section being only a quality for one, which has in no wise influenced the remaining result of displacement. And with the remaining observable result of effective displacement alone I am dealing at present.

What is called head resistance is indeed no more than the increase of volume of moving solid by shape causing part of the medium to also move with and as if a supplementary part of the solid volume, and may be treated as a special matter, when first the influence of volume be properly understood, and of shape in general for equal volumes. The effect being the same the resistance such as classified must be the same, and thus not the transverse major but average section is conditional to the measurement of resistance, and such resistance is in consequence properly expressed by

$$R=d^3\times R.o.V.$$

The effect of the indicated motion of the sphere is undeniably uniform, and not intermittent for all motion at uniform velocity. The displacement for the length of motion=v is in consequence the same as such by a body of equal length=1 having a uniform transverse section. And this uniform transverse section is in all possible cases=$d^2\times$R.o.V.

Thus the permanent, lasting constant effect of relative motion of submerged solid and submerging liquid is properly expressed as R=$d^3\times$R.o.V.

The next step to be taken in my elementary demonstration will be to consider the effects of motion and displacement by equal volumes with different axes in the direction of motion. I therefore make also use of a parallelopiped

$$B=1^3\times\frac{\pi}{6}=1^2\times\frac{\pi}{6}1=0.5236.$$

And I propose to consider the motion in submersion of this parallelopiped once in the direction of its axis $d^1=\frac{\pi}{6}$, and another time in the direction of its axis d^{11}=1. When moving on its short axis

$=d^1=\frac{\pi}{6}$ a total volume $=D(^1)$ is displaced within a moving distance $=V(^1)=\frac{\pi}{6}=d^1$.

When moving on its long axis $d^{11}=1$, a total volume $D(^{11})=\frac{\pi}{6}$ is displaced only within a moving distance $V(^{11})=1$, but in moving only a distance $V^1=\frac{\pi}{6}$ the resulting displacement D^{111} from motion on the axis $d=1$ would only be

$$D^{111}=\frac{\pi}{6}\times\frac{\pi}{6}=\frac{\pi^2}{6^2},$$

and therefore

$$D^1:D^{111}=R^1:R^{111}=\frac{\pi}{6}:\frac{\pi^2}{6^2}=1:\frac{\pi}{6}$$

By $R=d^2\times R.o.V.$

we have $R^1=\frac{\pi^2}{6^2}\times\frac{6^2}{\pi^2}=1,$

and $R^{111}=1^2\times\frac{\pi}{6}=\frac{\pi}{6}$

and $R^1:R^{111}=1:\frac{\pi}{6}$

or at the precise inverse rate of their submerged length measured in the direction of motion.

The result of this experiment, the full and further testing of which must also be left to critical readers, then would be applicable on ships and ocean travel in the following form:

"The resistance to two ships in motion both having the same amount of volume submerged, but being of different length, rates for one and the other at the inverse ratio of their (submerged) length measured in the direction of their motion, the shorter one, with same volume finding the greater resistance (under equal velocity), and a resistance increased *at the the same rate* as its (submerged) length in the direction of motion is shorter than that of the vessel of same submerged volume with which it is compared."

As early as November, 1881, I directed attention by publication to the fact, that a correct rating for resistance of ships for insurance purposes, for speed measurement, and for nautical construction may be obtained from this formula, (Comp. F. & M. Rd., Nov., '81.)

If in the light of these results we subject Mr. Thurston's proposition (3) to a critical test, we may establish the relative resistance $(=R^{(a)})$ of a hemisphere to motion by $R=d^2\times R.o.V.$ as $R^{(a)}=1^2\times\frac{\pi}{6\times2}$, as often as the diameter 1 is in the direction of motion. A cylinder of a transverse section $=\frac{\pi}{12}=0.2618$ with a length $d=1$ would produce the absolutely identical effect in displacement with equal velocity.

Which, then, is the elongated form "*which gives the minimum head resistance*," referred to by Mr. Thurston as *non plus ultra*, as between which and the hemisphere the practicable achievement must remain intermediate?

The displacement theory can give answer also to this query.

By building a vessel of the same submerged volume $R=\frac{\pi}{12}$ in the shape of two half cones of an elevation $=1$ with bases joined, the result will be a length $d=2$ and

$$\text{by volume}=2^3\times R.o.V.=\frac{\pi}{12},$$

and by $$R.o.V.=\frac{\pi}{8\times12},$$

and $$R=2^3\times\frac{\pi}{8\times12}=\frac{\pi}{24}.$$

Or, again, by doubling the length for the same volume the resistance is reduced to one half.

Therefore, there is good reason for lengthening the axis in the direction of motion, and good reason for facing motion with a sharp angle in order not to increase the moving volume, because real head resistance is the cause of moving a part of the liquid, as if it were a part of the solid.

It is sufficient to know that the essential conditions by which the resistance of a vessel to motion must be rated is its submerged volume as a consequence of its weight, and that the main quality lessening resistance thereof is the distribution of such given volume and weight over as great a length and as small a transverse average section as possible.

Proceeding then from the valuation of resistance $(=R)$ to valuating propelling

power required (=P), it follows from the facts, as shown, namely, that resistance does *not rate* as d^2 the square of length, and does not rate as MS, the transverse major section, that neither P the propelling power can thus rate.

The propelling question, or the question of overcoming such resistance to motion, demands

(*a*) The production of the highest mechanical power by the least weight of machinery and coal.

(*b*) The application of such power in the most effective method against the medium offering both the resistance to motion and to the propelling power applied.

All endeavors of late years have exclusively been in the direction of the point *a*. Since the substitution of the screw for the paddle-wheel no progress has been made in the direction of the point *b*, but as the world is ready for one step more, it will inevitably be made, and I would be much pleased if nautical constructors would deign to take the hint and try the pump once more, but this time taking the water from the ship's front and ejecting it sternward in a straight line in absolute conformity with the intended motion, taking the precaution to take up the water in a narrow vertical line at the head, and to eject sternward on as broad a face as practicable so as to lessen the resistance in the direction of motion, and to increase it where it is contributive to motion. In the method of jet propeller, hitherto exclusively tried, the inlets and outlets were in absolute conflict with the teachings of my new displacement theory.

"The ship of the next century" need not be, as Prof. Thurston forestalls it, a naval Babylonian tower, but it will be one of rational dimensions, being in harmony with such dimensions as the human race can properly master and control; but "*the ship of the next century*" will first apply its motive power in a more rational method than the propeller screw represents. The crank-shaft will be done away with. The water, to be moved from head to stern in order to produce relative motion, will be conducted not on a circuit around the good ship's body, but right through it lengthwise in a straight line, and the water rejected at the stern will steer the vessel. And the propelling power will be applied to the screw at its circumference, in place of its center if a screw be used at all. And in consequence the weight of machinery for exercising the same propelling power will be materially less. And the resistance of the water at the stern being increased, and the resistance at the head being lessened, the same amount of power will produce greater speed. Thus, not a "Leviathan" representing increased dimensions, but an "Investigator" representing the progress of human thought, will be "the ship of the next century."

THERMO-ELECTRICITY.

From "The Electrician."

ALTHOUGH many combinations of conductors producing a greater or less E.M.F. under the influence of heat have already been described, the search for bodies which possess this property has acquired a great interest on account of their possible application to thermo-electric generators. M. G. Chaperon has, according to the *Revue Industrielle*, methodically studied from this point of view a certain number of chemical compounds, chiefly chosen amongst those which can be easily reproduced in their active state. The method employed in this research is characterised by being applicable to fragments of any form whatever, and, if need be, of very small dimensions. It consists in applying two points of one of these fragments to two metallic walls, which conduct heat well, whose temperatures are evaluated as closely as possibly, and which serve as electrodes to show and measure the E.M.F. of the couple thus formed. One of these walls is that of a thin silver tube traversed by a current of water at the temperature of the surrounding air, and forming part of a pair of pincers with which the body under consideration is held. By means of these pincers a second point of the body is ap-

plied against a hot wall, that of an iron crucible full of fusible alloy, and into which a thermometer is plunged. Contact ought to be insured by a constant pressure. The procedure is then to measure during slow variations of temperature a series of values of the difference of potential of the two plates. The iron crucible is united to the electrical measuring apparatus by a silver wire sufficiently long for its extremity to remain cold. The E.M.F. measured is then, in virtue of the law of successive contacts, that of the couple formed by the body which is under investigation and silver. For certain compounds capable of attacking iron a thin leaf of silver is also interposed at their point of contact with the crucible. For more elevated temperatures another arrangement has also been employed, in which the hot contact is taken at a point of a silvered copper bar heated at one extremity. The temperature is evaluated at another point of the same section of this bar with a second body already studied, and which thus serves as thermometer. In the various couples thus formed the contacts of active substances with the electrodes ought to take place by small surfaces, which are as distant from one another as possible, in order that the temperatures of these contacts may be as nearly as possible those of the electrodes, which alone can be estimated. One thus obtains with substances in general bad conductors elements of an enormous resistance; therefore the rapid measurement of the E.M.F.'s is only rendered practically possible by the use of Lippmann's electrometer. Besides, this only serves to show the equilibrium of the force measured with that given by a potentiometer with wire of a reduced form giving $\frac{1}{5000}$th of a volt. It is possible with this conjoint apparatus to obtain sufficiently easily curves representing the law of variation of the E.M.F.'s as functions of the fall of temperature. M G. Chaperon then quotes some examples of measures thus made on substances little studied and enumerated below. Positive bodies: iodide of silver, phosphide of zinc, sulphide of tin, crystallised galena, oxide of copper in a very thin plate, arsenide of zinc. Negative bodies; sulphide of silver specular iron, crystallised galena. The curves representing the force as a function of the fall of temperature indicate in general a uniform increase starting from a certain point; they have been followed up to 250 or 300 degrees. Nevertheless, for the iodide, and, above all, for the sulphide of silver, the law of variation undergoes a sudden change, and hardly appears susceptible of being represented by a continuous function.

STRENGTH OF OBLIQUE ARCHES.

By JOHN L. CULLEY.

Written for Van Nostrand's Magazine.

Chapter VIII.

90. The static problems in masonry arches is to so construct, or so arrange the material composing the arch, that the line of pressure resultant from the weight and load of the arch shall pass through it in planes parallel with the arch faces, to the end that the arch stress shall be uniform throughout the length of the arch, and that the courses shall be relieved, as far as possible, of the tendency to move or slide over one another.

91. Without discussing the problems involved, we will suppose that the bond of the arch is ample to resist all ordinary external forces acting upon the arch, and that the arches now to be considered are so constructed that the line of pressure falls within the middle third of the thickness of the arch, and that it is located on the center line of the depth of the arch, as for instance on the middle line $a\,a$, Fig. 41.

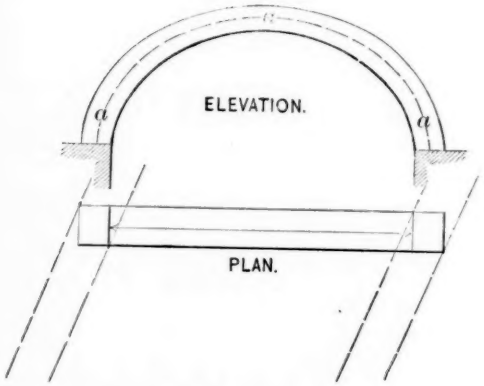
92. Undoubtedly the disposition of the material composing the arch has much to do in determining the direction of the line of pressures.

In a right arch the coursing beds being parallel with the spring lines or axis of

the arch, the line of pressure passes directly to the abutments in lines normal to those beds, and therefore in planes parallel to the arch faces. We have seen (article 24 and Fig. 11) that in an oblique arch with straight beds, there was a tendency for the arch stress to pass to the abutments in lines normal to such straight beds, and it would undoubtedly do so were it not for the distorted strains in the overhanging oblique ends of the arch.

Let Fig. 41 be an elliptical arch. With straight radial beds it is evident that the line of pressure will be parallel with the arch faces, and this is true if the arch is a single narrow rib. Now, an oblique arch may be regarded as composed of a number of elliptical ribs arranged as in Fig. 40. These ribs may be so narrow, that they will not break the continuity of the arch cylindrical intrados. The line of pressure in any single rib will be parallel to the arch face, and therefore the line of pressure for the whole arch must also be parallel with the arch face. The line of pressure would not be altered in this respect if the several ribs were reduced to the exact cylindrical intrados of the arch.

Fig. 41



93. Again, in a helicoidal arch there is always a point on either side of the crown, where the coursing beds are normal to the arch face.

Now, if the arch be limited by imposts or abutments at these normal beds, the line of pressure will evidently pass through the arch normal to the impost and in lines parallel with the arch face, the same as in a right segmental arch, provided that no bed between the imposts shall depart from the normal to the arch face, equal to the angle of friction. It will be shown directly that this departure, for arches of the least practicable obliquity never amounts to as much as one-half of the angle of friction. If the abutment be lowered below the normal beds the line of pressure will continue parallel to the arch face until a bed is reached whose departure from the normal to the arch face equals the angle of friction. Even then if the surfaces of this lower bed and those below it resist the tendency to move, the line of pressure will continue parallel with the arch face.

94. We conclude therefore that the line of pressure is parallel to the arch faces when the condition of greatest stability in an oblique arch is to be realized, and that it should be regarded as parallel to the arch faces in discussing the strength of oblique arch.

95. Perfect stability is realized when the coursing beds are exactly normal to the line of pressure. In the logarithmic method the generating line in the coursing beds is exactly normal to the arch face, and, therefore, practically complies with this condition of perfect stability, and needs no further discussion in this particular.

96. Let S X G, Fig. 42, be the end de-

velopment of the arch for the middle line on the arch face between the intrados and the extrados. S X G will also represent the direction of the line of pressure, since it is parallel with the arch face. Draw the straight line S X G, joining the extremities of the development, and draw

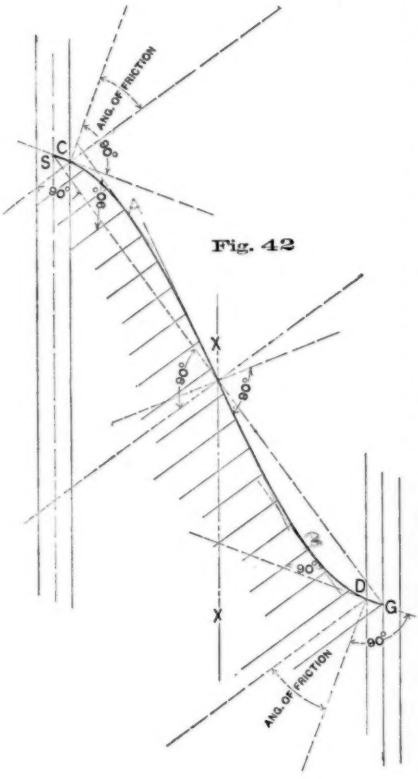


Fig. 42

the middle line of the coursing beds normal to this line, as heretofore described. At A and B these lines will be normal also to the line of pressure. X, the middle of the end development, is the point between A and B, of the greatest departure of the middle line of a coursing bed from the normal to the line of pressure. For an oblique arch of 25° obliquity this departure is only 12°, the arch, therefore, is for all practical cases perfectly safe between A and B. At C and D the middle course lines depart from the normal to the line of pressure equal to the angle of friction. And the courses below these points will slide over one another if not otherwise resisted. Between C and S the tendency will be for the courses to move over one another into the arch, and between D and G to move out from the arch. It will not be safe to construct the arch below D, unless precautions be taken to thoroughly resist the outward tendency of the courses between D and G. In an oblique arch of 25° obliquity the point D is 10° above the horizontal on the full semi-circular right section, the angle of friction being taken as 36°. The stability of oblique arches proves that the angle of friction for the courses of the arch must far exceed 36°, especially so for well cemented masonry. The arch of 25° obliquity would unquestionably be safe for 160° on the right section. At 40° above the horizontal the coursing beds in this arch would be normal to the arch face. If the arch below 10° was resisted by the wing walls, or if the courses were doweled to prevent slipping the whole arch could be made stable for a full semicircle on the right section. Such construction is not recommended. Segmental arches are far preferable. It is true, however, that full semi-circular helicoidal arches of slight obliquity have been built, that have given the most satisfactory results.

It should be noted the sliding tendency of the courses immediately back in the arch from its face between D and G, is opposed by the abutment of the arch, and therefore cannot move without disturbing the abutment.

That the courses in the arch face below D do not, in carefully constructed oblique arches, move the least outward, is accounted for by the fact that they are held tight in the arch by the weight of the spandrel or parapet wall above them; that is to say they are so tightly wedged into the arch as to overcome the outward tendency.

Fig. 42 is an exact drawing of the end development, an oblique arch of 25° obliquity for full semi-circular right section.

REFRIGERATING AND ICE-MAKING MACHINERY AND APPLIANCES.

By T. LIGHTFOOT.

Read before the Institution of Mechanical Engineers.

II.

III.—*Machinery by which a Gas is Compressed, partially Cooled while under Compression, and further Cooled by Subsequent Expansion.*

This subject having been dealt with in a paper on "Machines for Producing Cold Air," which the author had the honor to read before the members of this institution in January, 1881, the remarks under this head will therefore to a large extent be supplementary to that paper, and will refer chiefly to improvements which have been effected since that date. It will be convenient, however, and will tend to a better appreciation of the subject, to present concisely some brief considerations respecting the physical laws relating to this system of refrigeration, even at the risk of repeating part of the matter touched upon in the previous paper. The intrinsic energy of a permanent gas, or its capacity for performing work, depends entirely upon its temperature. Increase of pressure imparts no additional energy, but merely places the gas in such a condition relatively to some other pressure as to enable advantage to be taken of its intrinsic energy by expansion. Thus, a pound of air at ordinary atmospheric pressure has the same intrinsic energy as a pound of air at 50 lb. pressure above the atmosphere so long as their temperatures are the same; but in the former case no part of the energy can be made use of by expansion without the removal of, at least, a part of the equal and opposite resistance of the atmosphere, while in the latter case expansion can take place freely until the pressure is reduced to that of the atmosphere. As mechanical work and heat are mutually convertible, it is obvious that, if during the expansion a gas is caused to perform work on a piston, its supply of heat must be drawn on to an extent measured by the thermal equivalent of the work done, provided no extraneous source of heat exists from which the deficiency can be made good; and the gas after expansion will be colder than it was before expansion. Expansion behind a piston without the addition of heat from an extraneous source is called adiabatic expansion; and the following are the relations between temperature, volume, and pressure for any two points in the same adiabatic curve:

$$\frac{t}{t_1} = \left(\frac{v_1}{v}\right)^{\gamma-1} = \left(\frac{p}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

where t and v and p denote absolute temperature, volume, and absolute pressure before expansion, and t_1 v_1 p_1 those after expansion, while γ is the ratio of the specific heat under constant pressure to that with constant volume. During adiabatic compression the converse results take place, and the same relations exist between absolute temperature, volume, and absolute pressure, as during expansion: t_1 v_1 p_1 denoting those before compression, and t v p those after compression.

In the succeeding remarks reference will be made to the use of ordinary atmospheric air alone; for although in one or two special instances this class of machinery has been applied to the cooling of some of the more volatile hydro-carbons, its almost universal application at the present time is for the cooling of air, which therefore will alone be dealt with. The amount of aqueous vapor present in the atmosphere varies from that required to produce saturation down to about one-fifth of that quantity. At any given temperature a volume of saturated air can contain only one definite amount of vapor in solution; and if from any cause additional moisture be present, it cannot exist as a vapor, but appears as water in the form of fog or mist. The temperature of saturation, or the dew points, varies according to the quantity of vapor

in solution: the smaller the quantity, the lower is the dew point. The capacity of air for holding moisture is also affected by pressure: a diminution in volume under constant temperature reduces this capacity in direct proportion.* In the former paper reference was made to various means that had been devised for ridding the air more or less completely of its contained moisture, in order to obviate as much as possible the practical evils resulting from its condensation and freezing: this being at that time considered one of the most important points in the construction of cold-air machinery. Since then, however, experience has demonstrated that these evils were much exaggerated, and that the condensation of the vapor and deposition of the moisture in the ordinary cooling process after compression, which is common to every cold-air machine, are amply sufficient to prevent any serious deposition of ice about the valves and in the air passages: provided, firstly, that these valves and passages are well proportioned, and, secondly, that proper means are adopted for obtaining in the coolers a deposition of the condensed vapor, which would otherwise pass with the air into the expansion cylinder in the form of fog, and become converted into ice. Reference to the table shows that, if the compressed air be thoroughly deprived of its mechanically suspended moisture, the amount of vapor entering the expansion cylinder is extremely small. Another matter from which the mystery has now been dispelled is the meaning of the term "dry" air, so much used by the makers of cold-air machinery; this is a point that was just touched upon towards the close of the discussion upon the previous paper. No doubt it is still to a large extent popularly supposed that, unless the air be subjected in the machine to some special drying process, it will be delivered from the expansion cylinder in a moist or damp state, and in consequence be unfitted for use in the preservation of perishable food and for other purposes. But no such state could really exist; for whether the air be specially "dried" or not, its humidity when delivered from the expansion cylinder is precisely the same, so long as its temperature and pressure remain the same, in as much as in practice it is always in a saturated condition for that pressure and temperature. The difference lies in the amount of ice formed, which of course is greater if the amount of moisture entering the expansion cylinder is greater; but this quantity, as has been already stated, may in the author's opinion be brought down within perfectly convenient limits by a proper construction of the cooling vessels. In his latest machines, therefore, all special drying apparatus has been dispensed with: the air being simply compressed, passed through a surface cooler, and expanded back to atmospheric pressure. On the other hand, Messrs. Haslam & Co., of Derby, still apply an interchanger, on somewhat the same principle as that previously described in connection with the Bell-Coleman machine (*Proceedings*, 1881. page 111); and it would be interesting if some definite particulars could be furnished to show what practical effect this interchanger really has.

Messrs. Hall's cold-air machine is of both horizontal and vertical type, the latter applying to the smaller sizes. In either case, when combined with a steam engine, it consists of three double-acting cylinders placed side by side, at the end of a frame or bedplate; the cylinders are furnished with the usual moving parts, and the connecting-rods work on three crank-pins on a common crank-shaft. One of the cylinders is used with steam in the ordinary manner, for giving the requisite motive power. Of the two others, one is for compressing and one for expanding the air. The coolers are of the multitubular type for surface cooling, and are placed in the bedplate or frame. The valves for the compression and expansion cylinders are slides of somewhat peculiar design, worked from a pair of weigh-bars, one for the main and the other for the expansion slides. The valves are placed on the under-side of the cylinders, which renders them rather difficult of access; but in the larger sizes of machines the cylinders are raised, and work down to the shaft at an angle, which gives a little more room below. The compressor is water jacketed; and so far as the author is aware no special arrangement for drying the air is employed.

* For the quantity of vapor necessary to produce saturation, reference may be made to the table and formula given in the appendix to the paper on "Machines for Producing Cold Air" (*Proceedings*, 1881, page 122).

The Haslam dry-air refrigerator, which has been very largely adopted, is also made both horizontal and vertical, the horizontal type applying to large machines, and the vertical to those of small size. The cylinders are double-acting, and their arrangement with regard to one another varies in different classes of machines. The compressor is water-jacketed, and discharges into surface coolers placed in the bed. The compressed air, after having been cooled in the ordinary way by water, is further reduced in temperature in an interchanger, by the action either of the spent cold-air on its way from the chamber in which it has been utilised, or of the cold air as it leaves the expansion cylinder; and in this manner a further condensation and deposition of moisture are brought about. The expansion cylinder presents no peculiarity in design, with the exception of the exhaust valves, which are separate from those admitting the air, and are so arranged as to offer as little obstruction as possible to the passage of the air. The Haslam Company also manufacture the Bell-Coleman machine, which was described in the author's previous paper.

In a horizontal dry air refrigerator of the author's design, of the type used for delivering from 20,000 to 60,000 cubic feet of cold air per hour, the compressor is double-acting, and the expansion cylinder single-acting. They are placed close together, tandem fashion, leaving room for examination of the piston, with one rod common to both cylinders. In this way the coldest part of the expansion cylinder is removed from the hottest part of the compressor. The air-valves are circular slides of phosphor bronze, actuated by eccentrics in the usual way. This kind of valve enables the ports to be made very short and direct; and besides being noiseless in action, it allows of a high piston speed being attained. No trouble has been experienced with regard to wear, not a single case having occurred in which the valves have had to be replaced, notwithstanding that some have been in almost constant work since 1882. The air enters the compressor by pipes, and after being compressed passes by another pipe to the coolers, which are placed in the bedplate, and consist of a couple of iron vessels containing clusters of solid-drawn Muntz-metal tubes of ¾-inch external diameter. Water is circulated through the inside of the tubes by a pump, the supply passing in by one pipe, through the tubes, and away by another pipe to the compressor jacket, whence it escapes by a third pipe. The water condensed and deposited from the air in the coolers is blown off from time to time by means of drain cocks, or may be discharged automatically. The compressed air passes through one cooler and returns through the second, being cooled to within some 5° or 6° of the initial temperature of the cooling water, which circulates in a direction opposed to that of the air. The quantity of water required is at the rate of from 30 to 40 gallons for every 1,000 cubic feet of cold air discharged at atmospheric pressure, that is, from three to four times the weight of the air; but the quantity varies in different machines according to the efficiency of the apparatus. From the coolers, the air passes by a pipe to the expansion cylinder; and after performing work upon the piston, and returning about 60 per cent. of the power expended in its compression, it is exhausted from a passage, having become cooled down to from 70° to 90° below zero Fahr. The steam cylinder is overhung from strong brackets cast on the bedplate, and is arranged so that a jet or surface condenser can be placed below, with an air pump worked from a continuation of the piston-rod; the space occupied is thus practically the same, whether the engine is noncondensing or condensing. The arrangement also lends itself readily to the application of a second steam cylinder, tandem fashion, for working on the compound principle.

For land machines to deliver more than 60,000 cubic feet of cold air per hour, the vertical type is adopted, and the compressor is made single-acting as well as the expansion cylinder, while a horizontal compound condensing steam-engine is used for giving the necessary motive power. A machine to deliver 285,000 cubic feet of cold air per hour, for cooling a large market, is now being designed in this way. The compressor is furnished with an internal pipe, from which a spray of cold water continually plays on the back of the piston and on the sides of the cylinder, but never comes in contact with the air itself. In order to secure com-

pactness and simplicity, machines delivering less than 20.000 cubic feet of cold air per hour are made, the compressors being single-acting. The smaller sizes are very frequently made on the vertical plan, for use both on land and on board ship. The design is practically the same as that of the horizontal machines; but in the vertical type the coolers are cast in one piece with the frame, instead of being separate. There is a vertical machine of similar design, but arranged for being driven by a belt. The main objects kept in view by the author in designing all the foregoing machines are economy of production, efficiency, and simplicity, Some thirty of these refrigerators, of one form or the other, have now been made and put to work since 1884; and in not one single instance hat any breakdown occurred in working, nor have any repairs been required beyond those that would have been necessary to an ordinary steam engine of good construction. In many cases machines made in England have been packed and shipped to Australia, and to North and South America and other foreign countries, where they have been erected and put to work without the assistance of any skilled labor from this country. With regard to the power expended in cooling air on this plan, it may be stated that, in the best machines of large size now made, a weight of 1,000 lb. of air per hour can be reduced from 60° above to 80° below zero, with cooling water at 60° Fahr., with the expenditure of about 18 indicated horse-power. This is equal to an abstraction of 916 units per pound of coal, with an engine using 2 lb. of coal per indicated horse-power per hour.

IV.—*Considerations as to the Applications of the Various Systems.*

Under this head it is not intended to deal with the class of apparatus first described—for abstracting heat by the rapid melting of a solid, inasmuch as, excepting for domestic purposes in localities where other ice is not available, its application is wholly special and very limited, being confined almost entirely to the laboratory. Nor in regard to the machinery and apparatus in the second class—for abstracting heat by the evaporation of a more or less volatile liquid—need much be said, so far as ice-making and ordinary cooling are concerned; the various systems have already been explained in considerable detail, and sufficient information has been given upon which to base an estimate as to their economical application under any stated conditions. It is, therefore, chiefly with the machinery described in the third class that the present considerations will deal—namely, machinery by which a gas is compressed, partially cooled while under compression, and further cooled by subsequent expansion in the performance of work. Probably the earliest application of a refrigerating machine to manufacturing purposes was in 1861, when one of Harrison's ether machines was used by Mr. A. C. Kirk for the extraction of solid paraffin from shale oil. Since then the manufacture of paraffin has been developed to a large extent, and at the present time there are very few works engaged in its production without a refrigerating machine of one kind or another.* For the cooling of worts and of fermenting beer in breweries, refrigerating machines are largely employed. With English beer, which it is not necessary to cool below 50° Fahr., the general practice is to reduce the temperature of the cooling liquor by passing it through the refrigerator of the machine, the cooled liquor being afterwards used in an ordinary brewer's refrigerator. For larger beer, however, which is fermented at about 40° Fahr., the liquor is generally cooled by means of brine, and the temperature is brought down nearly to freezing-point. The same machine is in this country frequently employed for circulating cooled brine through a series of pipes above the fermenting tuns as well as for cooling the liquor; while in lager beer breweries the whole of the fermenting rooms and stores are kept, the former at about 42° Fahr., and the latter at about 31° Fahr., by means of cold brine circulating through pipes placed either on the ceiling or around the walls. For breweries, as well as for paraffin extraction, there can be no doubt that the most suitable machines to employ are those in which the cold is produced by the eva-

* Full information in regard to the most recent practice in paraffin cooling will be found in the *Journal of the Society of Chemical Industry*, May 29 and November 30, 1885, which contains papers by Mr. Beilby, describing the cooling machinery erected at the Oakbank Oil Works.

poration of a volatile liquid. Notwithstanding this, air-refrigerating machines have been applied for both purposes in certain special cases, and have given good results, though at a larger expenditure of fuel. There are many instances, however, in which the extra cost of fuel may be more than counterbalanced by the advantages resulting from simplicity and compactness, and from the absence of all inflammable or corrosive chemicals. Besides this the facility of application of cold-air machines is much beyond that of any other refrigerator. For these reasons they have been applied in dairies and in butterine works; in the latter case an additional advantage is gained from the rapidity with which the cooling can be accomplished, owing to the extremely low temperature at which the air is delivered from the machine.

The most extensive application of dry-air refrigerators, however, has been to the preservation of meat and other perishable foods. Explanations with regard to the general question of preservation by cold have already been fully gone into by the author in a paper on the "Preservation of Foods by Cold," read before the Health Congress at Brighton in December 1881; and it will therefore suffice here to state that, although it had long been known that at low temperatures the decomposition of animal matter was arrested for an almost indefinite period, yet the practical realisation of preservation by cold was prevented from being carried out for want of a simple and efficient means of artificial refrigeration. The attempts that had been made to produce a refrigerated atmosphere by means of ice had not given satisfactory results, owing, no doubt, to the moist state of the air, which, cooled by contact with melting ice, was necessarily saturated, and brought about a musty taste and loss of flavor in the meat preserved in it. In 1878, however, upon the successful development of the cold-air machine, it became possible to produce a cold atmosphere, which, even at a temperature of from 35° to 40°, never contained more than from 50 to 60 per cent. of the moisture required to saturate it. Under this condition all danger from excess of moisture as well as from excessive dryness was avoided; and the dry-air refrigerator was, therefore, speedily adopted for preservative purposes. Machines in which cold is produced by the evaporation of a volatile liquid have also been applied for preserving perishable foods. This has been done, either by cooling the rooms direct by means of overhead pipes through which the cooled brine is circulated, or else by causing a current of air from a fan to impinge against surfaces cooled by an internal circulation of brine, and by then passing the cooled air into the storage rooms. As to whether the air machine or that employing a volatile liquid is the best and most suitable, no general rule can be laid down. The simplicity, compactness, and readiness of application of the air machine have secured it a ready adoption in many cases where chemical machines would have been wholly inadmissible; but on the other hand the author considers that air machines have frequently been entirely misapplied. For use on board ship there can probably be no difference of opinion; and nearly the whole of the meat now imported into this country in a cooler or frozen condition is preserved by means of dry-air refrigerators, while in only one or two cases is a portion of it chilled and frozen on land by chemical machines.

The means adopted for the freezing and preservation of meat are very simple. They consist in lining the room, or the hold of the vessel, with material as impervious to heat as practicable. The construction of the lining is altered in different cases according to circumstances and to fancy; but it may be taken that an outer and inner layer of tongued and grooved boards 1 inch or 1½ inch thick, with a 9-inch space between filled with charcoal, form a fairly good protection, while in some cases silicate cotton may be used with advantage instead of charcoal. A little extra care and expense bestowed on the insulation of a chamber are soon repaid, for when the contents of the chamber are once reduced to the required temperature, the refrigerating machine has nothing further to do than to neutralise the heat passing through the walls, so that the more perfect the insulation, the greater is the saving in fuel, in wear and tear of machinery, and in attendance. The cold air from the machine is usually admitted by ducts placed near the ceiling, and after performing its cooling work it is led back

to the compressor, to be used over again, with the addition of a small amount of fresh air. In freezing, a temperature of about 10° Fahr., or even lower, should be maintained, and the carcases should be hung so that the air can circulate freely around them. If, however, the meat has previously been frozen, as is generally the case with the cargoes brought from abroad, which are to a large extent frozen on shore, the carcases are best packed as close together as possible, taking care to avoid injury through bruising, and to see that a free space is left for the cold air to circulate between the meat and the inner lining of the chamber. The temperature in this case need only be maintained low enough to leave sufficient margin in case of the machinery having to be stopped for any slight adjustment, or for oiling. The capacity of a machine to be applied in any given case is determined by a consideration, first, of the cooling work to be performed on the material contained in the chamber; and, secondly, of the amount of heat that will pass into the chamber from without. With regard to the first, nothing need be said here. The second quantity depends upon the area of the walls, floor, and ceiling, their construction, and the difference between the minimum internal and maximum external temperature. Experience has, of course, laid down certain general rules; but there are always special cases arising which require special treatment, and which can only be considered on the basis here set forth.

The trade in frozen meat has already necessitated the establishment of large stores, where the carcases are received and kept until they are required for consumption. A number of retail butchers also are now adopting cold stores of their own; such a storage arrangement is carried out in the vaults in Leadenhall Market for the preservation of about 20 tons of meat, partly frozen and partly unfrozen. A vertical dry-air machine is driven by an Otto gas engine, and by working from three to six hours per day supplies sufficient cold air for the four chambers. The temperature rises a few degrees during the night, and between Saturday night and Monday morning; but this is not found to be any disadvantage, and it has never yet been necessary to run the machine on a Sunday. The same water that is used for cooling the air cools also the gas-engine cylinder, and is afterwards used for heating the offices. The cost of the gas in this case is 1s. 3d. per hour. In view of the increasing demand for installations of this kind, the author has made arrangements with Messrs. Crossley Brothers to manufacture his dry-air machine in combination with the Otto gas engine, the gas engine simply taking the place of the engine there shown. In this way the cost will be reduced; and space also, which is generally very limited, will be saved. Similar installations have been erected for poulterers, game dealers, and butter salesmen, but need not be further referred to. In addition to the importation of dead meat, refrigerating machines of the horizontal kind shown in the diagrams have been applied for supplying fresh cool air for the ventilation of ships' holds in which live cattle are carried. In this way a temperature of 100° Fahr. has been reduced to 70° in the height of summer, and the loss of cattle has been entirely prevented. No doubt the same system could be equally well applied for the cooling and ventilation of buildings; but so far as the author is aware it has not yet been tried.

There are also arrangements on board passenger vessels for making ice, preserving meat, game, fish, and other perishable foods, cooling water, preserving vegetables, and cooling wine, beer, aerated waters, &c. This is a plan frequently carried out in large passenger vessels, and was introduced, the author believes, by Mr. Manuel, the engineering superintendent of the Peninsular and Oriental Company. The particular arrangement illustrated is one adopted in connection with a vertical steam-driven machine. The course of the cold air is indicated by arrows. In case of the vegetable room becoming too cold, ducts are provided by which the air can be led direct from the meat chamber to the machine. A somewhat similar arrangement of refrigerating plant is used in hotels; and the author's machines have been successfully applied for this purpose in the United States, though not as yet in this country. A recent application, also worthy of notice, is for preserving fish on board steam trawlers and on shore. Last year two of the author's vertical machines were sup-

plied for this purpose, one on a steam trawler, and one on a carrier, for use off the coast of Brazil, almost under the equator, in a climate where fish was hardly known as an article of diet, owing to the previously insuperable difficulties of preserving it in a sufficiently fresh state. The fish as soon as caught are placed on trays in an insulated room maintained at a temperature of about 35° Fahr. The experiment has been perfectly successful, and a further order for similar machinery is now being executed. In 1882 dry-air refrigerators were first applied to the cooling of chocolate by Messrs. J. S. Fry & Sons, of Bristol, who adopted one of the author's horizontal machines with the double-expansion arrangement described in his previous paper. Since then a number of similar machines have been applied for the same purpose in different parts of Europe and in the United States; and works which had to be entirely stopped in summer are now carried on during the whole year. The preservation of yeast, the cooling of gelatine dry plates, of fresh-killed meat in slaughter-houses, and the freezing of tongues in South America for exportation, have all been satisfactorily accomplished by the dry-air machine.

A rather remarkable application of refrigeration was made towards the close of last year by Captain Lindmark, of the Swedish Royal Engineers, who was engaged in the construction of a tunnel for foot passengers through a hill in Stockholm, on the top of which were built residential houses. The workmen came upon some ground, consisting of gravel mixed with clay and water, which had so little cohesion that the ordinary method of excavation had to be abandoned and the works stopped, owing to a subsidence in the earth above, which endangered the safety of the houses. Underpinning was out of the question, on account of the great expense. Under these circumstances it was decided to freeze the running ground, and to use cold air for the purpose as being most readily applied. One of the author's horizontal machines, capable of delivering 25,000 cubic feet of air per hour, was accordingly supplied by Messrs. Siebe, Gorman & Co., and was erected in the tunnel as close as possible to the required spot. The innermost end of the tunnel next the face was formed, into a freezing chamber by means of partition walls, which were made of a double layer of wood filled in between with charcoal. In the middle of last September the works were resumed. After the refrigerator had run for sixty hours continuously, the gravel was frozen into a hard mass to a depth varying from 5 feet near the bottom of the tunnel to 1 foot near the top. At the crown no freezing took place, and, though the temperature at the bottom of the chamber was as low as 40° below zero Fahr., a thermometer placed at the top, 16 feet above the floor indicated 32° above zero. This circumstance, however, was an advantage rather than otherwise, because, in any case, the roof would have had to be supported by planking, which would have been difficult to drive into the gravel had it been actually frozen at that part. The work was proceeded with in lengths of 5 feet, the excavation commencing at the top; and a temporary iron wall made up of plates 12 inches square was built in against the face from the top downward as the cutting away of the gravel proceeded. From 8 to 10 feet up from the bottom no protection was needed, as the frozen gravel formed such a hard, solid mass that it had to be removed with special tools. After once fairly starting, it was sufficient to run the cold-air machine, on the average, from ten to twelve hours every night, excepting after heavy rains, when much water percolated through the gravel. The machine worked all the time without a single hitch., and delivered the air at a temperature of 67° below zero Fahr. The temperature of the freezing chamber was generally from 6° to 15° below zero Fahr. after twelve hours' running; but it soon rose to freezing point when the men began to work. After two 5-feet lengths had been excavated, the partition wall was removed forward; the capacity of the freezing chamber thus varied from 3,000 to 6,000 cubic feet. The arching of the tunnel was completed as rapidly as possible close up to the temporary iron wall, while the ground was still frozen. This method of driving the tunnel was employed through a distance of about 80 feet with entire success. In the residential house to the north, neither subsidence nor cracks were perceptible three months after the tunnel was completed at this point. In the

house to the south, the front has subsided about an inch, causing some small cracks in the walls; but this house was not so well built as the other, subsidences having taken place in it before the tunnel was commenced. The daily progress while using the freezing process averaged about 1 foot. Although this is the first instance in which a dry-air refrigerator has been applied for the freezing of running ground, it is not the first in which refrigeration has been used for that purpose. As early as 1862 an ether machine was constructed by Messrs. Siebe, Gorman & Co., for freezing a quicksand met with in sinking a well. In that case pipes

TABLE I.—FREEZING MIXTURES.

Composition by Weight.		Reduction of Temperature in Degrees Fahrenheit.
Ammonium nitrate	1 part	From + 50° to + 4° = 46°
Water	1 "	
Ammonium chloride	5 parts	From + 50° to + 10° = 40°
Potassium nitrate	5 "	
Water	16 "	
Ammonium chloride	5 parts	From + 50° to + 4° = 46°
Potassium nitrate	5 "	
Sodium sulphate	8 "	
Water	16 "	
Sodium nitrate	3 parts	From + 50° to − 3° = 53°
Nitric acid diluted	2 "	
Ammonium nitrate	1 part	From + 50° to − 7° = 57°
Sodium carbonate	1 "	
Water	1 "	
Sodium phosphate	9 parts	From + 50° to − 12° = 62°
Nitric acid diluted	4 "	
Sodium sulphate	8 parts	From + 50° to − 0° = 50°
Hydrochloric acid	9 "	
Sodium sulphate	5 parts	From + 50° to + 3° = 47°
Sulphuric acid diluted	4 "	
Sodium sulphate	6 parts	From + 50° to − 10° = 60°
Ammonium chloride	4 "	
Potassium nitrate	2 "	
Nitric acid diluted	4 "	
Sodium sulphate	6 parts	From + 50° to − 40° = 90°
Ammonium nitrate	5 "	
Nitric acid diluted	4 "	
Snow or pounded ice	2 parts	To − 5°
Sodium chloride	1 "	
Snow or pounded ice	5 parts	To − 12°
Sodium chloride	2 "	
Ammonium chloride	1 "	
Snow or pounded ice	24 parts	To − 18°
Sodium chloride	10 "	
Ammonium chloride	5 "	
Potassium nitrate	5 "	
Snow or pounded ice	12 parts	To − 25°
Sodium chloride	5 "	
Ammonium nitrate	5 "	
Snow	3 parts	From + 32° to − 23° = 55°
Sulphuric acid diluted	2 "	
Snow	8 parts	From + 32° to − 27° = 59°
Hydrochloric acid	5 "	
Snow	7 parts	From + 32° to − 30° = 62°
Nitric acid diluted	4 "	
Snow	4 parts	From + 32° to − 40° = 72°
Calcium chloride	5 "	
Snow	2 parts	From + 32° to − 50° = 82°
Calcium chloride crystalized	3 "	
Snow	3 parts	From + 32° to − 51° = 83°
Potash	4 "	

TABLE II.—EVAPORATION OF LIQUIDS.

Liquid or Gas.		Water.	Anhydr's Ammonia.	Sulphuric Ether.	Methylic Ether.	Sulphur Dioxide.	Pictet's Liquid.
Specific gravity of vapor, compared with air = 1.000		0.622	0.59	2.24	1.61	2.24	—
Boiling-point at atmospheric pressure		Fahr. 212°	Fahr. -37.3°	Fahr. 96°	Fahr. -10.5°	Fahr. 14°	Fahr. -3.2°
Latent heat of vaporisation at atmospheric pressure		966°	900°	165°	—	182°	—
Absolute vapor tensions in pounds per square inch at different temperatures.	Fahr.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
	−40°	—	—	—	—	—	—
	−20°	—	19.4	—	12.0	5.7	11.6
	0°	—	30.0	1.5	18.7	9.8	15.4
	+20°	—	47.7	2.6	28.1	16.9	22.6
	+32°	0.089	61.5	3.6	36.0	22.7	27.0
	+40°	0.123	73.0	4.5	42.5	27.3	31.3
	+60°	0.254	108.0	7.2	01.0	41.4	44 0
	+80°	0.503	152 4	10.9	86.1	60.2	60.0
	100°	0.942	210.6	16.2	118.0	84.5	79.1
	120°	1.685	283.7	23.5	—	117.5	99.7
	140°	2.879	—	33.5	—	—	—
	160°	4.731	—	45.6	—	—	—
	180°	7.511	—	62.0	—	—	—
	200°	11.526	—	81.8	—	—	—
	212°	14.7	—	96.0	—	—	—

formed into a coil of larger diameter than the lining of the well were sunk into the quicksand, which was then frozen solid by circulating cold brine through the pipes. The excavation was then proceeded with, the lining put in, the circulation of brine stopped, and the coil removed. The same plan has recently been adopted by Mr. Poetsch in Germany in connection with the sinking of colliery shafts; but instead of a coil a series of vertical iron pipes are used, arranged in a circle, the effect of course being precisely the same. For driving the Stockholm tunnel, however, it is difficult to see how freezing by means of brine could have been applied, the excavation being horizontal instead of vertical.

Colonel Martindale said that in the year 1881 the London and St. Katherine Dock Company, of which he had the honor to be the general manager, were pressed by some of their Australian friends to make arrangements, for receiving frozen meat and storing and distributing it. They necessarily began on a very small scale. They had a large vault under one of the warehouses about 500 feet long and 64 feet wide, divided originally into four compartments. They made use of it for their storage. They commenced with a small engine, delivering 10,000 cubic feet of air per hour, from Messrs. Hall, of Dartford, and it did excellent work until 1884 when it was removed to make room for a larger one. They now had fifty-six chambers in two vaults. The smallest had a cubic content of 2,273 feet, the largest 9,280 feet, and the total content of the fifty-six chambers was more than 183 cubic feet. The carcases averaged in weight 56, 60, and 72 lbs., and if the chambers could be completely filled they would hold about 59,000 sheep of the first weight, 56,000 sheep of the second weight, and 44,000 sheep of the third weight, but in practice space had to be left to separate different marks and for gangways. A proportionate deduction, therefore, had to be made from what they could otherwise store; still they could always store forty-four

thousand sheep of the largest size. The construction of the chambers had varied a little in detail, but the last that had been built was according to the recommendation of Mr. Haslam, of Derby. There was a 1¼-inch boarding of rough boards on a concrete floor, and 4-inch bearers, at about 20 inches apart, to carry the floor; which was in two thicknesses of 1¼-inch boards, with prepared brown paper between them. The intervals were filled with carefully dried charcoal. The sides and roofs were similar in construction, and the whole of the boards were grooved and tongued. Air was conveyed by wooden trunks from the machines into the chambers, and pumped into them by slides in the trunks, the air coming in at one end close to the roof, and being drawn in at the other end also close to the roof. Most of the chambers were fitted with return air trunks, which had to be cleared out every twenty-four hours, and the engines' snow boxes about every four hours. A great loss of cold was experienced at every angle, and therefore all rises or falls should be conducted through sloping trunks. A properly insulated air chamber would not rise more than from 24° to 25° in twenty-four hours if the engines were stopped. They had at present four of Haslam's 60,000-feet machines and three of Hall's 30,000-feet machines. They were supplied with steam from the three multitubular boilers of the marine type and four boilers of the locomotive type. If they had to start afresh they would not have any boilers of the locomotive type. They had had to feel their way step by step, and the trade had grown upon them At the A jetty stores, a Haslam 60,000 feet machine was worked on 15 chambers of a total capacity of 48,000 cubic feet capable of storing 11,000 sheep of the average weight of 72 lb., but allowing for gangways, divisions, and marks, that 11,000 had to be reduced to 8,000 or 9,000. The engine was running twenty out of the twenty-four hours, the four hours' stoppage including the necessary time for clearing the valves, snow boxes, and air-trunks. The average speed was 80 revolutions per minute, at an air pressure of 44 lb. per square inch, giving a temperature of 57° below zero in the snow-boxes, and keeping the chambers down to a temperature of from 15° to 18° Fahr. In practice that was found to be about the best temperature at which to keep the meat. About 4½ tons of coal were used in the twenty hours. They had found that it gave better results in proportion to fuel to work at a pressure of 40 lb. to the square inch, instead of 50 lb. and upwards. In keeping such a low temperature in the snow-boxes, a greater volume of cold air was delivered into the chambers, when the proportionate loss in temperature was much less between the delivery from the expansion cylinder to the distant chambers. At the same jetty they had two of Hall's 30,000 feet machines working in fifteen chambers of the same capacity, and doing just about the same work. At the B jetty there were two of Haslam's 60,000 feet machines working on twenty-four chambers of 90,000 cubic feet capacity, and running at an average of 70 revolutions per minute, with an air pressure of 40 lb. per square inch, a temperature of 55° below zero in the snow-boxes, and a coal consumption of 4½ tons in the 20 hours. The loss of temperature in the delivery of air to the chambers at any distance was generally considerable. As a rule the chamber next to the engine was kept at a sufficiently low temperature without opening the delivery ports in the air-trunks. The air was delivered into the next chamber at about 9° Fahr., and into the most distant chamber, 165 feet from the engine, at from 16° to 18° Fahr. The greatest care ought to be taken in regulating the delivery and return air ports, gradually increasing the area in both in proportion to the increased distance. The greatest distance that the air was run was 180 feet. When the temperature of the nearest chamber was at 9° Fahr., they found the most distant chamber was at 18°, and therefore the loss in temperature in travelling was 1° for every 18 feet or 20 feet travelled. He did not want the institution to take that as a scientific result, but it was the practical result of the observations taken by the officers of the company extending over some time. Ninety hundredweight of coal worked the three engines giving out nominally 120,000 feet per hour for twenty hours. That reduced would give 2 lb. of coal required for every 240 feet of air delivered; but in practice they would have to rather increase that amount

because he did not believe the engines actually delivered the total quantity of air that was stated. The coal was ordinary Welsh coal, at about 16s. 6d. per ton. It was also found that from 1 foot to 1½ feet of air per hour would keep cool, say, at 18° Fahr.; 1 foot of storage at a distance not exceeding 180 feet, or at an average distance of 90 feet. The result that he first arrived at was that one foot of air would keep one foot of storage cool per hour, and Mr. Haslam had arrived at exactly the same conclussion, but allowing for delivery, openings, and doors, &c., he did not think they could put the quantity of air required at much under 1½ feet per hour for every foot of storage that they wished to keep down to 18°. If the meat was to remain undisturbed and in large measures, they would probably be able to do with one foot of cool air for every foot of storage.

A communication was then read from Mr. Colyer, in which he stated that one of the first machines made on Mr. Harrison's system was still at work at Messrs. Truman, Hanbury & Co.'s brewery, and was acting very efficiently. It had been there for about thirty years. He thought the consumption of coal actually stated in the paper at 2 lb. per hour was too low, and that 3 lb. or 4 lb. would be nearer the mark. Machines for carrying water and making ice might be divided into two classes: one in which ether was used, and one in which ammonia was used. In London, where coal was dear, and water often had to be obtained from the water companies, the ether system was far more expensive than the ammonia system.

Mr. Gorman said that the machine at Messrs. Truman's was made by the late Mr. Siebe, and was the first made under Mr. Harrison's patent except the one that was taken to Australia.

Mr. Harrison said the latent heat of ammonia was set down in the paper at 900°, and the latent heat of sulphuric ether at 165°, but the practical working latent heat of ether in the ice-making process was 656° instead of 165°. The figures given by Mr. Lightfoot were correct as regards equal weights of the different substances at the atmospheric pressure, but the ice-maker dealt with measures of capacity. A vacuum pump was a measure of capacity, and to apply the latent heat of equal weights to the quantity passed by a pump was of course altogether inaccurate. Then again, the ice-maker did not work at the atmospheric pressure, and all vapors which were used under lower pressure were of greater latent heat. Latent heat was increased in proportion to the tenuity of the vapor, and if the ice-maker worked at a temperature above the atmospheric pressure there must be a deduction for latent heat lost. In that way the latent heat of ammonia had to be reduced from 900° to 845°, because in using ammonia they worked at a pressure in excess of the atmospheric pressure. There were other points connected with the temperature of condensation, which, in his opinion, brought ammonia and ether very nearly on a level. In point of fact, he thought that of all the different refrigerating agents there was no one better than another. If in any case one seemed to be more efficient than another, it was simply because the principle had been better carried out in that process.

Mr. Price Williams said he had recently had an opportunity of examining the refrigerating process on his voyage out to Australia, and he must bear testimony to the admirable way in which it served its purpose. In this country the question of refrigeration for the preservation of meat was really becoming one of very great importance. In a letter to him not long ago, Sir William Armstrong drew a picture of what a terrible thing it would be for this country if the freedom of navigation were destroyed, and if England lost the supremacy of the sea even for one day. Australia was now able to send any amount of food that could be taken here, but it was regarded as a great mistake to freeze the meat. It seemed to be considered that the arrangement must be such that the meat should not be reduced to freezing, but should be kept as near to the freezing-point as possible. As the refrigerating process had been carried out successfully in ships' holds for purifying the air when live cattle were imported, he thought it might be of very great advantage at times to the berths on board ships. He made an estimate, and the engineer agreed with him, that by the expenditure of the small sum of £700 on board the vessel in which he went to Australia, a constant temperature of 60° or 70° might be maintained. If

the P. and O. Company would carry out that suggestion, they would add very largely to the comfort of their passengers, and induce people to make journeys to the torrid zone much more frequently than they did now.

Mr. Halpin said that when once the chamber was got down to the temperature it was desired to run at, of course all the machine then had to do was to overcome the leaks of heat being transferred through the walls. The importance of the covering was therefore very great, because a large amount of power and coal was being used. He had lately made some experiments in Germany with cork as a non-conductor. The French had used that material for many years before, and brought it out in the 1878 Exhibition; but the trouble in the French arrangement was the expense. They took the ordinary cork, and cut it up in slices, and got a good effect, but at very great expense. In Germany, however, all the refuse and waste cork was ground into powder and cemented together again, and it made an exceedingly cheap material. The broad results of his tests were that 92 or 93 per cent. of the transfer of heat was totally arrested; in other words, that only 7 or 8 per cent. of the heat went through.

Colonel Martindale wished to add that if chemicals were used in producing the cold it was an absolute necessity that the air delivered should not have the faintest trace or smell of chemicals. No consignee would keep his meat in any store where he could detect the slightest smell of that kind.

Mr. Schönheyder said that the cold air was admitted near the ceiling of the chamber and the hot air was also taken away near the ceiling. It seemed to him that if, in these cold air machines, there was any chance of snow getting in with the air, it had a great opportunity of doing so when it was admitted near the ceiling, and of falling on to the meat, and possibly deteriorating it. The air might just as well be admitted near the floor. It would then gradually rise as it picked up heat from the carcases, and could be extracted from near the ceiling.

Mr. Lightfoot, in reply said that the snow difficulty had never arisen. He had never found the snow fall on the meat, and if the meat was frozen he did not think it would matter if the snow did fall on it. He did not agree with Mr. Price Williams, but thought that the meat must be frozen. Unless it was frozen decomposition would take place. It might be kept at a temperature of 35° for three weeks, but beyond that time it was impossible, because a slow process of decomposition and of chemical change took place, and the simple question was how much of that could be allowed before the meat was eaten. On the other hand, when the meat was frozen no chemical change of any kind took place. There was a slight mechanical change, and the cellular tissue was to some extent destroyed, and consequently when the meat was thawed there was a loss of juices.

CORROSION OF THE COPPER OF THE JUNIATA.

By CHARLES E. MUNROE.

From Proceedings of United States Naval Institute.

On October 23, 1882, I received telegraphic orders from the Secretary of the Navy to proceed to New York and examine the Juniata, with the object of ascertaining the cause of the corrosion of her copper. On reporting there I found the Juniata in dry dock, and an examination of her copper showed that the immersed surface had become covered with a pale green, earthy-looking coating, which at the time had become dry in spots, and blistered. Many of these blisters had split, and the coating had flaked off to such an extent that the floor of the dock was thickly strewn with them. While the outer surfaces of these scales were of an apple-green color, the inner was, in the main, of a copper-red color, though in some instances it was black. The surface of the copper where thus exposed was, in the main, of a copper-red color, but in some spots black. Where these

black spots appeared they were imperfectly circular in shape.

In addition to this general action which had caused the incrustation over the entire wetted surface, it was found that several plates had been so corroded as to be nearly or completely perforated. Eleven sheets on the keel, and sixteen on the bottom, most of them below the turn of the bilge, were so badly corroded as to require removal, and there were many others which gave promise of being soon in the same condition. This corrosion did not involve the whole of the plate on which it existed, nor was every plate attacked, nor in most cases contiguous plates, nor did it, in any case observed, extend to the nails or about them. The action was so irregularly distributed about the bottom and on the surface of the plates attacked, that there could be little doubt that the cause at work was a purely local one. Where corrosion had gone on to the extent described, the outline of the spot was irregularly circular in shape, and the areas decreased unevenly from the outer surface inward, giving to the perforation an irregular cone-shape of very wide angle, the sides of the cone being in steps. The copper at these points seemed to be laminated.

Further inspection showed that a portion of the copper on the keel, and all of the copper on the rudder, was covered with a greenish incrustation which was harder, firmer, and more coherent than that on the remainder of the ship, and that this copper was *wholly* free from any evidences of corrosion. The portion on the keel was midway fore and aft at the top of the keel. It was a goring-shaped section, and, roughly estimated, it was fifty feet in length, and tapered from eighteen inches wide midway to a point at either end. Although this strip was wholly free from local corrosion, yet sheets of copper below it, on the keel, and above it, on the hull, were corroded as described. So on the stern there were several corroded sheets, while the copper on the rudder, immediately adjacent, was free from all evidences of it. From their location it was evident that this copper on the rudder and the top of the keel had been subjected to the same conditions of exposure after immersion as the remainder of the copper on the immersed surface.

The history of the Juniata was officially given as follows: When she had received her suit of copper, she was removed from the dry dock and lay in the Wallabout, under the iron derrick, for about five months; she was then moved to the wharf at the foot of Main street, near Store No. 30, where she lay for one and a half months. From there she was moved to the ordnance dock, where she remained three days; again moved to the foot of Main street, where she lay for a day and a half, and then was taken into the dry dock again. This was two days before I reported in New York. The corrosion noted had consequently taken place during the six to seven months in which the vessel was lying in the Wallabout. The copper on the rudder and the goring-shaped section on the keel were said to have been a portion of the old suit of copper which had been put on at the League Island Yard some years before. The goring-shaped piece owed its form to the fact that the ship was "hogged," and when pieces were inserted to straighten up the keel, it was thought unnecessary to strip the old copper from the old keel.

My attention was next turned to the examination of the new, unused copper from which the copper for the Juniata had been taken. I first, while examining the bottom, inquired of the workmen if they had noticed any peculiarity in the appearance of the copper as they put it on, and I found that they had remarked upon the "picturing," as they termed it, which seemed to be unusual. I applied then for sheets of copper from the same batch, and found that a few remained in the storehouse. On inspection I found that this "picturing" of which the workmen spoke was in the form of irregularly circular black spots and streaks on the surface of the copper. My first impression was that these spots were probably due to the fact that during transportation moisture had gathered on the surface of the plates, and that this moisture had absorbed hydrogen or ammonium sulphide from the bilge gases of the ship in which they were transported, and that this had tarnished them; but on examining the spots by light reflected at a wide angle, and by the sense of touch, it seemed probable that the plates had been rolled since the spots were formed, since the

lustre on the spots was quite as brilliant as elsewhere on the surface. This theory of staining was not credited in the Constructor's Department of the Yard, as it was generally understood that the sheets were in this condition when put aboard the transport boat.

I next directed my efforts to tracing up the history of the Juniata copper. I hoped to ascertain when it was received and where it was rolled; then from the marks upon the sheets to learn from what batch of copper it had come; then to follow up these cakes to the smelting works, and from this point determine the source and character of the ore from which it was made. With this knowledge of the source of the copper and the various processes through which it had passed, I hoped to discover the source of any physical or chemical imperfections which the sheets might contain; but at the outset I found that there were no marks upon these sheets of copper by which they could be identified, and that the different invoices received at the New York Yard were so mixed as to be indistinguishable. All that I could learn was that all of the sheathing used was rolled at the Washington Yard. Since such difficulties as have arisen in the case of the Juniata's copper are likely to recur, it will assist materially in discovering the source of the difficulty if the history of the copper is known. I would recommend that hereafter a full record of the copper should be kept, and that each sheet should be stamped in the upper left-hand corner with the number of the batch from which it comes. This mark will be preserved by the lap of the sheet above. That this is feasible is shown by a sheet of the old copper, stripped some two years previously from the Brooklyn, after it had been some years in service, which bears distinctly the following mark in left-hand upper corner, "U. S. N. Y. W., 1866." Starting from this point it will then be possible to compile from the log-books of a ship such statistics regarding the time the copper has been in use, and the conditions to which it has been exposed. as will enable us to determine the average life of copper sheathing—an important fact about which there now seems to be considerable uncertainty.

I next examined the Wallabout, a crescent-shaped body of water, something over 400 feet wide, lying between the Navy Yard proper and the cob dock. With the flood tide the current passes through to the westward, and with the ebb tide it moves to the eastward. Emptying into it are three sewers. At the east end, opposite the ordnance dock, is the Williamsburg sewer, which drains 2,300 acres of improved property, a considerable part being covered by petroleum refineries, chemical works, sugar refineries, and the like. About 500 feet from the dry dock the Brooklyn sewer, which traverses the Navy Yard, empties into the Wallabout. This drains an area of about 550 acres of improved property largely covered by residences. Near Store No. 30 a small sewer empties which drains a portion of the Navy Yard; and near the west end of the Wallabout the Hudson-avenue sewer, which drains 472 acres of Brooklyn, empties. The result of all this sewage flowing into the Wallabout is to modify very considerably the character of the sea water. The first effect observed is that which always takes place where sewage, charged with dissolved and suspended matter, flows into salt water —viz.: the precipitation of the suspended and dissolved matter and the formation of mud banks. This is going on continually in the Wallabout, and one of the largest banks was formed under the iron derrick where the Juniata lay for about five months. So shoal was it that she rested in the mud at low water, and, in fact was probably imbedded in it for the greater part of the time. From this bank I gathered specimens of the mud, and I also got specimens of the bottom from off the ordnance dock. The first was regular dock mud, but the second consisted largely of coal tar. This last was accounted for by the existence about opposite of two large gas works, the "People's" and the "Nassau," while at the west end of the Wallabout there is a third. From the Williamsburgh and the Brooklyn sewers samples of sewage were taken. The color and character of the sewage as it flowed from the sewers showed that the first was from factories, while the second was largely from dwellings. All the samples of sewage and mud were tested immediately after gathering, and all were found to be slightly *acid*. Naturally the character of the

sewage flowing in, and consequently of the water in the Wallabout, will vary with the season, the day, and the state of the tide, so that the examination of only one set of samples is not of any value, except as indicating the character of the water at the time they were gathered. Realizing this, I applied to the Health Department of the City of Brooklyn, and also to Professor Chandler, President Board of Health of New York, for information concerning the sewage emptying into the East River, but no investigation of this sort seems to have been made. Professor Chandler says, however, "There are a great number of petroleum refineries on Long Island at Hunter's Point and at Newtown Creek, and these refineries use enormous quantities of sulphuric acid, some portions of which find their way into the river. There are also chemical factories in Brooklyn—quite a number of them—and possibly their refuse materials are discharged from the sewers, by which the water along that shore may be rendered quite different from ordinary sea water." Through the courtesy of Civil Engineer F. C. Prindle, U. S. N., and Mr. J. H. Raymond, Commissioner of Health of the City of Brooklyn, I have obtained much of the information concerning the sewers which is given above. It would seem likely that considerable ammonia would reach the Wallabout from the gas works, were it not that ammonia has become so valuable an article, and the processes for recovering it from gas works have become so improved as to prevent much of it being allowed to escape. It is probable, too that the considerable deposit of coal tar discovered at the end of the ordnance dock accumulated before these by-products of gas-making had become of any commercial value.

Besides the specimens of mud and sewage, one sheet of new copper from the lot from which the Juniata's copper was probably taken, five corroded sheets stripped from the Juniata, a strip of the copper from the rudder of the Juniata, and a sheet of the old copper which had been stripped from the Brooklyn when she was last recoppered here, were taken for examination.

Before leaving the Navy Yard I examined the pile of old copper stripped from the Brooklyn when she was last repaired. Although this had been in service many years (just how long I could not ascertain), much of it was so strong that it drew out the nails in coming off. Some of the sheets were eaten through in much the same way as was seen in the Juniata's copper, but there were very few of them. Naval constructor W. L. Mintoyne, U. S. N., informed me that sheets of this old copper had been used for covering the anchor hoy used in the Wallabout, that these sheets had been in use thus for about two years, and that during that time the anchor hoy frequently rested on the mud banks, yet the copper was sound. Mr. Mintoyne also described some experiments which he had made with the Juniata's copper. He took sheets from the lot with which the Juniata was sheathed, and coupled them in pairs by blocks of wood. At the time the Juniata was copper he buried one of these pairs in the mud; the second was suspended six feet from the surface of the water, and the third was suspended at the surface of the water at low-water mark. These couples remained until the Juniata was docked in October, 1882. They were then taken out, and all were found unchanged except the couple buried in the mud, and these were only tarnished.

During my inspection of the bottom of the Juniata I was accompanied by Naval Constructor-in-chief T. D. Wilson, U. S. N., and he suggested in explantion of the corrosion that it was due (1) coming in contact with the copper, and that this probably occurred while the Juniata was lying in the mud bank under the iron derrick, as it was rumored that iron chains and other iron articles had been lost in this mud bank from time to time. Since my visit to the Navy Yard this mud bank has been removed by dredging, but I cannot learn that any such articles have been recovered.

Another theory (2) advanced to account for the corrosion is that it was due to the sewage which flows into the Wallabout in such quantity. This was evidently in mind when my orders were drawn, as they read: "Your attention is called to the fact that a large sewer discharges into the Wallabout at a point near the wharf to which the Juniata has recently been moved."

Another (3) is that it was due to impurities in the copper, arising either from imperfect refining, impure ores, or the intentional admixture of foreign and cheaper metals.

Another (4) is that it was due to iron removed by abrasion, or in the form of rust, from the rolls in the rolling mill.

Another (5) is that it was caused by the adhesion of coal tar.

Another (6) is that it was due to physical or chemical differences in different parts of the copper, which were caused by the method of manufacture.

On the 6th of December, 1882, in obedience to orders I proceeded to Washington, and there examined the sheets of corroded copper from the U. S. S. Brooklyn which were sent from Rio Janeiro. The corroded sheets presented practically the same appearance as those from the Juniata. There was the same irregularly circular outline, and the corrosion was seen in all stages, from a roughened surface at the outer edge of the circle to a thin edge at the center. Through the courtesy of the Chief of the Bureau of Construction, I examined the report of the condition of the Brooklyn, with the accompanying drawings. These sketches showed that there was no regularity in the distribution of the corrosion, though most of the corroded sheets were below the turn of the bilge.

On the 9th of December, in obedience to orders, I proceeded to New York to examine the U. S. S. Trenton, then in dry dock. On inspection, I found her copper to be in a very sound condition, so far as local corrosion was concerned, the only corroded plates being six about each of the Kingston valves, one plate on the starboard side in contact with the stern being roughened, but not pierced, and one on the port side forward, just below and in contact with the ram. Besides these, there were a few plates which had been indented and torn slightly, probably through colliding with some object. In addition, I found that one sheet had been removed from the garboard stroke on the port side, about 60 feet aft. I could not learn why this plate had been taken off.

The history of this copper, so far as I could gather it, is as follows: The Trenton was on commission in Europe for some years, and on her return in October, 1881, she was laid up at the New York Yard. I am informed by her commanding officer, Captain F. M. Ramsay, U. S. N., that when she was brought in she was laid alongside the iron derrick, and she was so heavily loaded that it was with great difficulty that she could be forced into the mud bank under the derrick. After lying there some time she was drawn out into the Wallabout, and from that time until she was put into the dry dock, in December, 1882, she lay nearly opposite the mouth of the Brooklyn sewer. The conditions, then, to which her old copper was subjected were almost identical with those to which the Juniata's new copper was subjected, the chief difference being that as the Trenton was heavily loaded, while the Juniata was light, the Trenton probably sank much deeper in the mud bank than the Juniata did.

On December 20, 1882, in obedience to orders I proceeded to Washington to inspect the rolling mill at the Washington Navy Yard, then in operation. Here I witnessed the operations of hot rolling and scaling, and my attention was particularly attracted to the latter process, as it did not seem to be complete, some portions of the scale being adherent after the removal from the bath, necessitating the cleaning of the sheet as completely as possible by mechanical means. As the treatment with the lye and acid was done in a very crude way, by rubbing on with a broom, this may account, in a measure, for the failure to entirely remove the scale or oxide. During my visit I was the recipient of courteous attentions from Commodore T. Pattison, U. S. N., commanding, and from Naval Constructor S. H. Pook, U. S. N., in charge of the rolling mill, and the latter permitted me to take copies of letters, of recent date from the managers of some of the principal rolling mills in the country, from which I extract the following:

Park, Scott & Co., Lake Superior Copper Mills, Pa., say: "The rolls in our mills which have given the most satisfaction are semi-steam chilled." "We are not experienced as to what action seawater may have on sheathing made with iron rolls."

C. G. Hussey & Co., Pittsburgh Copper and Brass Rolling Mills, Pa., state: "For rolling copper we use principally

the chilled-iron rolls, and as far as our experience has gone we find them well adapted for the work. We never knew of any iron from the rolls adhering to the copper, but black spots may be on the copper from imperfect removal of the scale or oxide. That is the only way we can account for black spots or marks."

Hendricks Brothers, New York, write: "We consider chilled-iron rolls the best for the purpose referred to, and when replacing any at our own works, do so with those of that description. The rolling of copper in iron rollers is not detrimental for sheathing, nor would they injure it in any way as regards the action of sea water. The black spots spoken of are not iron, but copper scale or oxide, and do not affect the quality. Copper may be of equal purity, but some are harder than others; the latter are preferred for the sheathing for vessels, on account of the action of salt water upon it."

Pope & Cole, Baltimore, Md., write: "The only suitable material for the construction of rolls for rolling copper is *best iron, chilled.* The arrangements for rolling copper at the Washington Navy Yard are, in our judgment, so good that some time since we availed of permission from head quarters to make copies of the working drawings in your mill, with the purpose of constructing one here, upon your method, in place of our present mill. The methods and surroundings of rolling copper have nothing whatever to do with the action of sea water upon copper sheathing on vessels. The trouble in cases where copper sheathing has become *honeycombed*, or *quickly worn thin* when in contact with sea water is attributable to the fact of the presence of a little silver in copper, which is quickly attacked by salt water. Copper for rolling can be procured which has no silver whatever in it—not a trace. The black specks or spots which you referred to are not iron: they are the oxide of copper. Copper and oxygen have a wonderful affinity for each other, especially when copper is hot or in a molten state. The oxide of copper, or, as known in commerce, "copper scale," is easily removed from sheets by "pickling," and ought to be wholly removed before your sheets are cold rolled. If you will heat a piece of bright polished copper, and then expose it for one moment to the atmosphere, it will so quickly absorb oxygen therefrom as at once to become as black as iron."

During this visit I received the following information from the executive officer of the Powhatan: "The Powhatan was lying at the wharf of the Brooklyn Navy Yard, near the iron derrick, from November 15, 1879, to January 23, 1880, and from December 23, 1880, to March 24, 1881. Shortly after each of the above occasions of her stay off the Navy Yard she went into the dry dock, and upon examination the copper on the bottom of the vessel was found in perfectly good condition." The conditions of exposure of the Powhatan evidently differed from those of the Juniata only in the fact that the latter was lying in the Wallabout during the summer months, while the former was there during the winter. This would, to an extent, probably modify the action.

On December 28, 1882, Commander Pattison, U. S. N., sent me the following samples: Ingot copper, Pope & Cole; ingot copper, Hendricks Bros.; copper cake, Pope & Cole; copper cake from refuse copper refined at the Washington Navy Yard. The ingot copper from Pope & Cole was full of air holes; the rest of the samples were sound, fine grained, and quite free from air holes or cavities, the specimen from the Washington Navy Yard being especially so.

On December 12, 1882, I received the following letter:

"Bureau of Ordnance,
"Navy Department.
"Washington City, Dec. 11, 1882.

"Professor Chas. E. Monroe, Chemist,
"U. S. N., Academy.

"Sir,—In connection with the condition of the copper sheathing on the Brooklyn, I beg leave to say (as probably throwing some light on the subject) that the copper on the ferry boat Billow, at the Torpedo Station, put on in May last, is very badly pitted.

This metal was furnished by the Bureau of Construction and Repairs, and the following analysis made* at the Torpedo Station shows that it contains foreign matters:

* By Professor J. Fleming White.

	Per cent.
Copper	98.492
Lead	0.172
Arsenic	0.290
Nickel	0.102
Cobalt	0.010
Iron	0.570
Oxygen	0.240
Zinc	0.272
	100.148

"Also traces of silver and antimony.

"This copper may have been taken from the same lot from which the Brooklyn was coppered. The Bureau will be glad to make other analyses of copper, if desired. I am, sir, your obedient servant,

"MONTGOMERY SICARD,
"Chief of Bureau."

In reply to my inquiry as to the conditions to which the Billow had been subjected, Capt. T. O. Selfridge, U. S. N., commanding the Torpedo Station, states that "the Billow never has been aground since the copper was put on, and that she has only been exposed to the action of pure sea water."

Learning that there had formerly been trouble from the water of Baltimore Harbor, I addressed a prominent shipbuilding firm there, and received the following reply:

"BALTIMORE, MD., Dec. 14, 1882.

"C. E. Monroe, Professor, U. S. Naval Academy.

"DEAR SIR,—Replying to your favor of 9th inst., in reference to the corrosion of copper and metal on vessels' bottoms in Baltimore Harbor, we would state that previous to the stopping of the sugar refineries and the deepening of our harbor, all the steamboats whose landings were in the vicinity of the refinery or at the foot of the street where the sewage of the latter was discharged suffered very much, and had to be docked for repairs or renewal of metal once each year, and in some cases at the refinery wharves twice in one year. The metal would be eaten worst at the water line around the nails in the seams of the plates. Some of the boats that used iron for protection against ice put it on in the fall and had to remove it in the spring, because it would be eaten away at the water line and interfere with the boat's running. All these boats now run two, three and four years without docking, and if they have pure copper on, we find it good after four years. We have some cases that we attribute to inferior metal. One we have just completed, the ship St. Albans, engaged in the Atlantic trade, metal been on twenty-six months, in active use eighteen months, honeycombed badly and had to be removed; should have lasted forty months. Yours respectfully, etc.,

"WILLIAM E. WOODALL & Co."

In considering the case of the Juniata we must bear in mind that it is to be expected that copper sheathing will corrode in use, and that the peculiar advantage which it offers for keeping a ship's bottom clean is due to the fact that the copper is acted upon by sea water and forms a salt which, as it dissolves or scales, carries off the barnacles or seaweeds with it, and that this corrosion goes on over the whole immersed surface and continues throughout the whole period of immersion.

What takes place with sound copper in pure sea water, will occur in any solvent in which the copper is immersed. If there is no contact with other bodies, solid or gaseous, and no marked currents formed in the liquid, corrosion will take place equally over the whole surface of the copper, though the speed of the corrosion may differ with the solvents.

What is peculiar about the corrosion of the Juniata's copper is that it was local and abnormally rapid. We will now take up the various theories proposed to account for this.

1 and 4. That it was due to contact with iron.

On January 22, 1824, Sir Humphrey Davy said: "The rapid decay of the copper sheathing of His Majesty's ships of war, and the uncertainty of the time of its duration, have long attracted the attention of those persons most concerned in the naval interests of the country. Having had my inquiries directed to this important object by the Commissioners of the Navy Board, and a Committee of the Royal Society having been appointed to consider of it, I entered into an experimental investigation of the causes of the action of sea water on copper.

"It has been generally supposed that

sea water has little or no action on pure copper, and that the rapid decay of the copper on certain ships was owing to its impurity. On trying, however, the action of sea water upon two specimens of copper sent by John Vivian, Esq., to Mr. Faraday for analysis, I found the specimen which appeared absolutely pure was acted upon even more rapidly than the specimen which contained alloy; and on pursuing the inquiry with specimens of various kinds of copper which had been collected by the Navy Board and sent to the Royal Society, and some of which had been considered as remarkable for their durability, and others for their rapid decay, I found that they offered very inconsiderable differences only in their action upon sea water; and, consequently, that the changes they had undergone must have depended upon other causes than the absolute quality of the metal.

"When a piece of polished copper is suffered to remain in sea water, the first effects observed are a yellow tarnish upon the copper and a cloudiness in the water, which takes place in two or three hours. The hue of the cloudiness is first white; it gradually becomes green. In less than a day a bluish-green precipitate appears in the bottom of the vessel, which constantly accumulates, at the same time that the surface of the copper corrodes, appearing red in the water, and grass-green where it is in contact with air."

Pursuing his experiments, Davy showed that there must be free oxygen present in water in order that copper might corrode, for "copper in sea water deprived of air by boiling or exhaustion, and exposed in an exhausted receiver or an atmosphere of hydrogen gas, underwent no change, and an absorption in atmospherical air was shown when copper and sea water were exposed to its agency in close vessels."

From his investigations Davy ascertained that when copper, in contact with a metal which was electro-negative to it, was exposed to sea water, the electro-negative metal was attacked, and the copper was free from corrosion until the other metal was destroyed; and he proposed to protect sheathing by this means. "In pursuing these researches and applying them to every possible form and connection of sheet copper, the results were of the most satisfactory kind. A piece of zinc as large as a pea, or the point of a small iron nail, was found fully adequate to preserve forty or fifty square inches of copper, and this wherever it was placed, whether at top, bottom, or in the middle of the sheet of copper; and whether the copper was straight, or bent, or made into coils. And where the connection between different pieces of copper was completed by wires, or thin filaments of the fortieth or fiftieth of an inch in diameter, the effect was the same; every side, every surface, every particle of copper remained bright, whilst the iron or the zinc was slowly corroded.

"A piece of thick sheet copper containing on both sides about sixty square inches was cut in such a manner as to form seven divisions, connected only by the smallest filaments that could be left, and a mass of zinc of the fifth of an inch in diameter was soldered to the upper division. The whole was plunged under sea water; the copper remained perfectly polished. The same experiment was made with iron; and now after the lapse of a month, in both instances, the copper is as bright as when it was first introduced, whilst similar pieces of copper undefended in the same sea water have undergone considerable corrosion, and produced a large quantity of green deposit in the bottom of the vessel.

"A piece of iron nail about an inch long was fastened by a piece of copper wire nearly a foot long to a mass of sheet copper containing about forty square inches, and the whole plunged below the surface of sea water; it was found, after a week, that the copper defended the iron in the same manner as if it had been in immediate contact.

"A piece of copper and a piece of zinc soldered together at one of their extremities were made to form an arc in two different vessels of sea water, and the two portions of water were connected together by a small mass of tow moistened in the same water; the effect of the preservation of the copper took place in the same manner as if they had been in the same vessel." (*Phil. Trans.* 1824, p. 151.)

On p. 242 *Phil. Trans.* 1824 Davy gives a report of additional experiments on the protection of copper sheathing. He says: "Sheets of copper defended by

from $\frac{1}{40}$ to $\frac{1}{1000}$ part of their surface of zinc, malleable and cast iron have been exposed for many weeks in the flow of the tide in Portsmouth Harbor, and their weights ascertained before and after the experiment. When the metallic protector was from $\frac{1}{40}$ to $\frac{1}{150}$, there was no corrosion nor decay of the copper; with smaller quantities, such as from $\frac{1}{200}$ to $\frac{1}{400}$, the copper underwent a loss of weight which was greater in proportion as the protector was smaller; and, as a proof of the universality of the principle, it was found that even $\frac{1}{1000}$ part of cast iron saved a certain proportion of the copper.

"The sheeting of boats and ships protected by the contact of zinc, cast and malleable iron in different proportions, compared with that of similar boats and sides of ships unprotected, exhibited bright surfaces, whilst the unprotected copper underwent rapid corrosion, becoming first red, then green, and losing a part of its substance in scales.

"Fortunately, in the course of these experiments it has been proved that cast iron, the substance which is cheapest and most easily procured, is likewise most fitted for the protection of copper. It lasts longer than malleable iron or zinc; and the plumbaginous substance which is left by the action of sea water upon it retains the original form of the iron, and does not impede the electrical action of the remaining metal."

In *Phil. Trans.* 1825, p. 328, Davy gave the results of his "Further Researches on the Preservation of Metals by Electro-Chemical Means." He said: "As long as the whole surface of the copper changes or corrodes, no such adhesions (barnacles, etc.) can occur; but when this green rust has partially formed, the copper below is protected by it, and there is an equal action produced, the electrical effect of the oxide, submuriate and carbonate of copper formed being to produce a more rapid corrosion of the parts still exposed to sea water; so that sheets are often found perforated with holes in one part, after being used five or six years, and comparatively sound in other parts.

"There is nothing in the poisonous character of the metal which prevents these adhesions (barnacles, etc.). It is *the solution* by which they are *prevented* —*the wear* of the surface. Weeds and shell fish readily adhere to the poisonous salts of lead which form upon the lead protecting the fore part of the keel; and to the copper, in any chemical combination in which it is insoluble.

"In general, in ships in the Navy, the first effect of the adhesion of weeds is perceived upon the heads of the mixed metal nails, which consist of copper alloyed by a small quantity of tin. The oxides of tin and copper which form upon the head of the nail and in the space around it defend the metal from the action of sea water, and being negative with respect to it, a stronger corroding effect is produced in its immediate vicinity, so that the copper is often worn into deep, irregular cavities in these parts.

"When copper is unequally worn, likewise in harbors or seas when the water is loaded with mud or mechanical deposits, this mud or these deposits rest in the rough parts or depression in the copper, and in the parts where the different sheets join, and afford a soil or bed in which seaweeds can fix their roots, and to which zoophytes and shell fish can adhere.

"As far as my experiments have gone, small quantities of other metals, such as iron, tin, zinc or arsenic in alloy in copper, have appeared to promote the formation of an insoluble compound on the surface, and consequently, there is much reason to believe, must be favorable to the adhesion of weeds and insects."

Up to July, 1824, all Davy's experiments had been tried in harbor in comparatively still water, but soon after the protectors were tested on a steam vessel in the North Seas, and it was found that sheets of unprotected copper one foot square lost about 6.55 grains in passing at a rate of eight miles per hour in twelve hours; but a sheet of the same size defended by rather less than $\frac{1}{50}$ lost 5.5 grains, and like sheets defended by $\frac{1}{10}$ and $\frac{1}{100}$ of malleable iron each lost two grains. These experiments show that there is a mechanical wear of the copper in sailing, and which, on the most exposed part of the ship and in the most rapid course, bears a relation of nearly 2 to 4.55. The copper sheets used weigh from 7,000 to 8,000 grains, and the balance would detect a difference of $\frac{1}{100}$ of a grain in carrying this load.

Further experiments showed that when air was excluded from a vessel containing sea water in which iron and copper or other corrodible metals were immersed, no action took place, and that the addition of an alkaline substance, even in presence of air, was sufficient to arrest corrosion; but if the solution was *strongly* alkaline, then the electro-chemical action was reversed and the copper was corroded while the iron was preserved. The results of applying protecting masses of iron to coppered ships are cited, and the effect seems to have been advantageous; but no instance is given where it had been tested for any long period.

In closing, he says: "The copper used for sheathing should be the purest that can be obtained; and in being applied to the ship, its surface should be preserved as smooth and equable as possible, and the nails used for fastening should likewise be of pure copper; and a little difference in their thickness and shape will easily compensate for their want of hardness."

In the *Comptes Rendus*, 59, 15, 1864, M. Becquerel reviews Davy's work, and records the work which he himself carried on at Toulon under the direction of the Minister de la Marine, which confirmed the views as to the protective action of iron on copper when immersed in sea water.

In the *Trans. Inst. Nav. Arch.*, 10, 166, 1869, John Grantham, Benjamin Bell, Charles Lamport, John Scott Russell, and C. F. J. Young, all testify to the destruction of iron in contact with copper, and the latter quotes Faraday, Wood, Normandy, Selwyn and Siemens in support of his views. These conditions, however, only hold true for sea water in an acid or neutral condition. At the time of my visit to the Wallabout I found the water and mud slightly acid, and if this be the prevailing condition of the Wallabout, it is impossible that the corrosion of the copper could have been due to the presence of iron.

But while this relative action holds good for acid and neutral solutions in general, in most alkaline solutions, and especially solutions of the alkaline sulphides, the reverse is true and the copper becomes electro-positive and is dissolved, while the iron remains unacted upon. Davy pointed this out in 1812 (*Chemical Phil.*, p. 148), and again, in 1825 (*Phil. Trans.*, p. 339); and Faraday, in his *Experimental Researches in Electricity*, Vol. II., p. 86, gives tables of the electro-chemical series for different solutions which show these facts. In order to test these statements I made experiments, taking solutions of ammonium carbonate and Severn-River water, and ammonium sulphide and Severn water. In each of these I inserted a strip of iron and one of copper in contact with each other and allowed them to stand. In 24 hours there was evidence of corrosion on the copper, and in one case where the action had gone on for two months, the copper was eaten off to the surface of the liquid, and copper was deposited on the iron. The solution contained 10 cm. of yellow sulphide of ammonia of the ordinary strength to 200 cm., of water, and during the time spoken of the solution was in an open flask in a dimly-lighted hood. No quantitative experiments were made, since it was not important for this research in the case of the ammonium carbonate, and in the case of the ammonium sulphide the coating of sulphide on the copper made it difficult to determine the loss with any degree of accuracy.

In determining if such a condition of circumstances could occur in the Wallabout we may learn something from the examination of the sewage waters and mud. The sewage water taken at the mouths of the sewers was collected in patent-stoppered lager-beer bottles, which were carefully rinsed with the water to be collected. Although tolerably free from odor when collected, by the time they reached Annapolis they were highly charged with gases, which proved to be largely sulphide of hydrogen and some sulphide of ammonia. Through decomposition they had become much more turbid from suspended matter than when first collected. So great was the pressure upon the bottles that, though they were kept in a cool place, one of them burst under the pressure of the confined gases. The sewage had become alkaline when it reached Annapolis. I give below the analyses of these waters, filtered, and of the sedimentary matter, and I add an analysis of the Severn River water, since I used this in some of the

experiments. The analyses given hereafter are usually the mean of several:

Parts in 100,000.

	Solids.			Ammonia.		
	Vol.	Non-vol.	Total	Am. Al.	Am.	Salt.
Wm'sb'g	261.6	583 6	845.2	.1420	.1250	385.5
B'klyn...	118.6	160.8	279.4	.0758	.0472	135.2
Severn..	150.0	1236.0	1393.0	....	....	1054.7

SUSPENDED MATTER.

Parts in 100,000.

	Vol.	Non-vol.	Total.
Williamsburgh.....	31.2	84.0	114.2
Brooklyn.....	22.6	38.1	50.7

The result of such sewage as the above flowing into salt water must be, not only the production of mud banks, as stated above, but also the generation of hydrogen sulphide and alkaline sulphides, for the salt water contains calcium sulphate (in pure sea-water it will rise to 100 parts in 100,000), and when organic matter comes in contact with this, calcium sulphide is formed, which gives off its sulphur as hydrogen sulphide when it comes in contact with the carbon dioxide of the air. Ammonium sulphide will then be formed through reaction with the sewage.

MUD.

The mud was stored in new paint-kegs immediately after collecting, and on arrival here it was transferred to air-tight glass jars. When the mud from under the iron derrick was dried, it was of a bluish-white color, and contained a considerable number of shells. It effervesced somewhat with acids, and when moistened it had a clay-like appearance. On drying, it gave off a slight offensive odor of animal matter. The mud from off the ordnance dock appeared, on drying, to be a mixture of blue mud with coal tar, and gave off the odor of coal tar on drying. The mud from the iron derrick lost 15.23 per cent. of volatile matter on ignition, while the mud from the ordnance dock lost 24.51 per cent. When treated with ether, both yielded a yellow extractive matter, which on evaporation gave off an acrid odor. Both samples, after exposure, became alkaline.

We see, then, that in the sewage emptying into the Wallabout we have materials for the formation of ammonium and other sulphides, and that, although at the time of my visit there the water was acid to neutral, yet, under the varying conditions prevailing, it is possible there are times when it may be alkaline. Is it, then, probable that iron in alkaline solution was the cause of corrosion? I think not, and for the following reasons:

If iron had fallen into this mud bank, it is probable that owing to its greater relative weight it would sink through the soft mud to the bottom. Now, there was considerable difference in height between the corroded plates highest up on the hull and those on the keel, and if the Juniata touched bottom on the keel, the iron in contact with the higher plates must have been buoyed up. Since, however, there was room for the much heavier Trenton to get in, it is probable that the Juniata did not touch hard bottom. This argument may, however, be met by supposing that both the vessels lay in a trough in the bottom of the Bay.

Another consideration is that the corrosion is too local for simple contact. None of the holes were over two inches in diameter, nor the roughened spaces about them more than eight inches. Now, copper is a good conductor, and with sheets as thick as these it seems strange that the action should be confined to so small an area. I do not lay much stress on this point.

What seems to me conclusive is that both the Powhatan and the Trenton lay in the same berth without injury, and that the copper on the rudder of the Juniata and the goring-piece on the keel were under precisely the same conditions as the remainder of the copper on the Juniata, and they were not corroded; and finally, that the copper on the Billow was corroded in a similar way without having been exposed to like surroundings.

2. That it was due to sewage. Since household sewage may contain sodium carbonate and hyposulphite from the soap used and zinc chloride and bleaching powder from the disinfectants employed, I tested the action of these substances upon both copper and oxide of copper, the substances and the solutions being enclosed in stoppered bottles. The following are the results after seven months' action:

Copper and sodium hyposulphite—copper coated with sulphide—no copper in solution.

Copper oxide and sodium hyposulphite—no copper in solution.

Copper and sodium carbonate—copper

quoted with green carbonate—considerable copper in solution.

Copper oxide and sodium carbonate—faint trace of copper in solution—the copper oxide unchanged in appearance.

Copper and zinc chloride—deep green deposit of copper chloride on sides of bottle—copper bright.

Copper oxide and zinc chloride—no action.

Copper and bleaching powder—copper coated with bluish coat—copper in solution.

Copper oxide and bleaching powder—trace of copper in solution.

All of these substances act upon the copper, but the last two would be destroyed by the organic matter in the Wallabout, and the first two would probably not exist any length of time in their original condition. But granted that any of them were present and free to act, or that there were free acids or ammonia or ammoniacal salts present, could they produce such corrosion as took place on the Juniata? In my opinion not, because they would be dissolved in the water or in a layer at the surface, and would produce corrosion over the entire immersed portion of the copper or else at the water line, while that of the Juniata was purely local and confined to widely and irregularly separated spots.

3. That it was due to impurities in the copper arising from imperfect refining, impure ores, or the intentional admixture of foreign and cheaper metals.

In the paper by Davy quoted above, it will be seen that the presence of iron, tin, zinc, arsenic and the like, in small quantities, promoted the formation of insoluble scale on copper. In Pope and Cole's letter we see that they attribute corrosion to the presence of silver. This view was advanced by A. A. Hayes (*Am. Jour. Sci.* [2] 11,324). He says: "Some analyses I made, many years since, of sheathing copper which had long resisted the action of sea water proved the presence of one ten-thousandth part of silver. It was found that even this small portion of silver sensibly modified the chemical relations of the metals and observations had indicated that the quality for sheathing was improved. Copper of this kind is frequently met with in commerce, and is derived from the Chilian ores of copper, which, although argentiferous, do not yield enough silver to render its separation economical.

"An occasion offered for again examining this subject, when the argentiferous native copper of Lake Superior was first refined and rolled by the Revere Copper Co., more than five years since, and the results have lately been obtained. Four suits of sheathing for large merchant vessels, formed the subjects for observations, the metal being of uniform composition, as determined by assay of the clipping from many sheets. Two thousand parts of the alloy contained four parts of pure silver, or the standard ton of this country contained four pounds of silver (0.20 per cent.).

"A *proximate* analysis of this metal was also made, and it proved to be pure copper throughout, the mass of which, an alloy of silver and copper, was evenly distributed so as to form either a mixture or a compound alloy, in which one part of the copper is truly combined with the silver, and the other and larger part simply combines with the alloy. This is a very common constitution of alloys, in which two metals exist without any metalloid occurring to disturb the simplicity of the union, and always indicates a careful purification of the metals.

"It was assumed as probable that the silver alloy would close the pores of the copper, which takes place with a tin alloy in bronze, and, in a mechanical way, confers durability. If, however, corrosion should take place, it was in accordance with observed cases that the silver alloy would act as a negative element, and the copper alone would be removed. How erroneous these inferences proved will be seen in the detail of the results.

"The Chicora was coppered January 9, 1847, taking 7,392 pounds of metal, which was fastened with bronze nails. She was employed in trade to China, and wore her copper so rapidly that it was removed in March, 1849, 2,628 pounds only remaining. In this case the sheets, after the usual operations, had been consolidated by 'cold-rolling.'

"The Serampore was coppered January 18, 1847, requiring 8,447 pounds of 'cold-rolled' metal, secured by bronze nails. She sailed to China and home *via* Cape of Good Hope, and to the Pacific and home *via* Cape Horn, requiring new copper in March, 1850. The weight of

the remaining copper was not ascertained.

"The Hamilton was coppered October 22, 1847, requiring 7,706 pounds metal, secured by bronze nails. The sheets used were in the ordinary or annealed state. This vessel was employed in the India trade, and wore out her copper in August, 1849. The weight of the copper remaining was 3,086 pounds.

"The Carthage was coppered November 26, 1847, requiring 8,727 pounds 'cold-rolled' metal, fastened by bronze nails. She was employed in the India trade, and her sheathing was destroyed in August, 1849. The copper remaining weighed 5,810 pounds.

"Omitting the case of the Serampore, where the corrosion cannot be determined by weight, we have the loss in every one hundred parts of metal, for the time of duration, thus: The Chicora, twenty-seven months, lost 64.45 per 100; the Hamilton, twenty-three months, lost 59. 95 per 100; the Carthage, twenty-one months, lost 33.45 per 100.

"Allowing the same rate of corrosion, and taking the time as 27 months for each: The Chicora lost 64.45 in 100; the Hamilton lost 70.38 in 100; the Carthage lost 43.00 in 100.

"In the cases of the Hamilton and Carthage we perceive the influence of the different processes of manufacturing the sheets on the durability of the copper. By the operation of 'cold-rolling' the surfaces of the sheets are rendered very compact, and in any corroding solution they bear a negative relation to the metal in the same sheets between these surfaces. Such copper is also always strongly negative to annealed copper in acid solutions until the hardened surfaces are removed; it then loses this relation. The Hamilton exhibits the greatest effect of sea-water action on the annealed alloy, while in the Carthage the protecting influence of the hardening surface was exerted nearly to the time her copper was removed. These observations establish the fact of the rapid corrosion of an alloy thus constituted, and show its entire unfitness for sheathing purposes.

"The average duration of copper sheathing decreases slightly as the requirement of greater speed in sailing is more urgent. Taking one hundred merchant ships, sailing on different oceans, the average duration now on American ships is three years.

"On the point of the *kind* of corrosion following the exposure of the alloy to sea water and air, the information obtained of these trials is of a definite character. Part of the sheets remaining, and an ingot of the copper from smelting a large quantity, were assayed, and the results showed that the same proportion only of silver remained as was originally contained in the alloy. The silver, therefore, by taking the negative state in the mass of the metal alloy hastened its destruction, while its own form and condition were such that it separated as the copper was corroded."

In this connection I made the following analyses. In these analyses I designate the copper from the rudder of the Juniata as "rudder copper," that taken from the Juniata after corrosion as "old Juniata copper," that taken off from the Brooklyn, in order to put on her present suit, as "Brooklyn copper," and the new sheet from the New York storehouse as "new Juniata copper."

In the analyses of the coppers, I have followed the methods given by Andrew A. Blair, chemist to the United States Board for Testing Metals, which appear as an appendix to Ex. Doc. 98 of the Forty fifth Congress, Second Session; and I have also employed the method of W. Hampe, given in *Zeitschrift für Analytische Chemie*, 176, 1874, and in Watts' *Dictionary of Chemistry*, Vol. VIII, Part 1. The methods have sometimes been modified in a measure, to accommodate them to the appliances at hand. In the table, the "rudder copper" is No. 1; the "Brooklyn," No. 2; the "new Juniata," No. 3, and the "old Juniata," No. 4. The results given are the mean of a number of determinations:

	1.	2.	3.	4.
Copper...	99.428	99.225	98 426	98.509%
Silver.....	.125	.085	.005	.010
Arsenic...	trace.	none.	.135	.159
Antimony.	none.	none.	.008	.005
Lead.....	.010	0.80	.178	.152
* Iron....	.183	.252	.650	.580
Nickel....	none.	none.	.050	.010
Zinc.....	none.	none.	.170	.150
Bismuth..	.005	.003	.012	.015
Oxygen...	.155	.185	.280	.235
	99.906	99.830	99.914	99.825

* In examining the copper for iron, I deemed it important to test the nitric acid used, although it was

For comparison with these, I have sought to obtain analyses of different American coppers from the principal sources, in order that we might determine what would be termed "pure copper" in commerce here, but I have been unable, as yet, to obtain such, so I give (1) an analysis of a "refined copper," from Oker, made by Hampe, and reported in Fresenius' *Quantitativen Chemischen Analyse*, 2, 527; 1882; (2) an analysis of a "refined copper" from Colorado, made by T. Egleston, Ph. D., and given in *Trans. of American Institute of Mining Engineers* for October, 1882; (3) an analysis of "ingot Lake Superior copper" Andrew A. Blair, *loc. cit.* 295.

	1.	2.	3.
Copper	99.325	99.705	99.420%
Silver	0.072	0.135	0.014
Gold	0 0001	..	..
Arsenic	0.130	0.091	none.
Antimony	0.095	..	none.
Bismuth	0.052	..	none.
Lead	0.061	none.	trace.
Iron	0.063	0.031	0.013
Cobalt	0.012	..	..
Nickel	0.034	..	..
Sulphur	0.001	trace.	..
Oxygen	0.1166	..	..
Tellurium	..	0.083	..
Zinc and nickel	..	0.024	..
Suboxide of copper	..	..	0.537
Carbon	..	..	0.041
	99.9917	100.069	100.025

The Juniata copper, then, is not so pure as the rudder copper or the Brooklyn copper, or the copper last cited. The excess of silver in the rudder and Brooklyn coppers may at first excite remark, but we must remember that both of these coppers had been exposed to sea water for a very long time, and that sea water contains chloride of silver in solution, and that silver will be deposited upon copper under these circumstances. Mulder, in his *Die Silber-Probirmethode*, 27, states that chloride of silver is soluble in solutions of all the metallic chlorides which are soluble in water. Watt's *Dictionary of Chemistry*, 5, 271, states that silver had been detected in sea water and refers to *Ann. Ch. Phys.* [3] 27, 129, which I have not been able to consult, and T. Sterry Hunt, *Chem. and Geol. Essays*, 231, repeats this statement. To test it, I placed some freshly precipitated and washed chloride of silver in Severn water and inserted a strip of copper. In twenty four hours a decided coating of silver was deposited on the copper.

The amount of silver present in the Juniata coppers seems, however, too small to have been the source of this trouble, and of the other substances found, the oxygen appears the one most likely to have been the cause of the trouble. It should be said that the darker, spotted portions of the new sheets were taken for analysis, and that on especially removing the surface from some of these spots by the aid of a bright steel file scraper, I found it to consist of a film of oxide free from sulphide. But as from the first my attention and that of others had been called to this unusual feature in the copper, and as these spots closely resembled the corroded spots in form, it seemed proper to select these portions. I am not, however, assured that a portion of the oxide did not originally exist in the copper.

The following experiments were made to ascertain if corrosion would take place between copper and copper oxide in the presence of the materials in the Wallabout. Heavy, cold-drawn copper wire was cut into pieces. Each piece was then bent, and one end was heated in the flame until it was coated with oxide. The strips were then immersed in the solutions or buried in the mud, as given in the table below. We then had an electro-chemical couple with copper and oxide of copper. In the experiments cited below, No. 5 and No. 6 were the most satisfactory as regards the cleanliness of the copper after removal from the solution and washing:

bought, as chemically pure, through Desaga, of E. Merck, of Darmstadt. The first bottle examined was but partially full, and had been standing for some time in strong sunlight, and was evolving nitrous fumes, notwithstanding that the glass was of a dark green color. Analysis showed it to contain .0035 gram of iron in 100 cm. Another full bottle of the same lot, which had been standing in the dark, was tested, and was found to be free from iron. This last was used in the analyses.

Substance used.	Loss.	Remarks.
	Per cent.	
1. Copper and Williamsburgh sewage.....	1.42	Liquid alkaline—contained coal tar.
2. Copper oxidized and Williamsburgh sewage.	1.45	Liquid alkaline—contained coal tar—copper pitted.
3. Copper and Brooklyn sewage.....	3.42	Liquid faintly alkaline.
4. Copper oxidized and Brooklyn sewage.....	2.99	Liquid faintly alkaline—copper pitted.
5. Copper and mud from under shears and Severn water.....	7.24	Liquid faintly alkaline—no pitting.
6. Copper oxidized and mud from under shears and Severn water.....	14.64	Liquid faintly alkaline—copper badly pitted.
7. Copper and mud from Ordnance Dock and water.....	4 06	Liquid alkaline—no pitting.
8 Copper oxidized and mud from Ordnance Dock and Severn Water.....	3.06	Liquid alkaline—copper faintly pitted.

As in these cases the solutions were all slightly alkaline, I repeated the experiments with Severn River water, and with common salt solutions, and in each case the copper was corroded. In addition, I connected my couple with a galvanometer and got a marked deflection of the needle. Hence there can be no doubt that electro-chemical action can go on between copper and copper oxide in sea water. This view is supported by the fact that all authorities are agreed that the corrosion of pure copper by pure sea water cannot take place in the absence of air. This air supplies oxygen, and the first step in the process of corrosion is one of oxidation. If, then, the copper be oxidized when immersed, the process is facilitated.

5. That it was caused by the adhesion of coal tar. In the examination of the Juniata, no coal tar was observed in contact with the corroded spots, though small amounts were noticed elsewhere, the copper at those points being sound. In the experiments last cited, when coal tar was present it adhered to the copper so firmly that it was difficult to remove it, and it formed a strongly adherent varnish or lacquer which seemed to protect the copper from corrosion.

6. That it is due to physical or chemical differences in different parts of the copper which were caused by the method of manufacture. From the consideration of all the circumstances, and especially of the facts that the copper is found to be *spotted* with oxide; that these spots are irregularly distributed over the plates; that they generally agree in configuration and size with the corroded spots, and that the copper at the corroded spots appears laminated, I am led to conclude that this theory is the more probable one, and that the imperfections result from blister-holes in the copper and the incomplete removal of the scale.

We have found that in the existence of these spots of scale or oxide we have a condition which is favorable to the commencement of the corrosion. Why does it continue?

If we examine one of the corroded spots from which the surface has been removed, we find that the remaining surface is roughened. Now, such a surface is more readily attacked than a polished surface. This latter is a well-known fact in connection with the "rusting" or corrosion of metals, and it is for this reason largely that metal articles are polished. But it seems to me that there is an additional reason for action at this point. In the *Proc. Nav. Inst.* 8, 502 I have shown that annealed steel is much more soluble in sea water than "tempered" or hardened steel, and that when in contact the soft metal is rapidly corroded. I have recently been confirmed in the truth of my observations by the investigation of M. Gruner in *Comptes Rendus*, 96, 195. I am inclined to the opinion that the same holds true of copper of varying hardness, and I find support for my opinion in the statement of A. A. Hayes.* I believe that the copper beneath the

* *Loc. cit.*

spots of scale is softer than that about it, and furnishes the differences necessary for this action.

My theory to account for the existence of these differences and for the formation of the spots is as follows: I assume that an unsound cake of copper is taken for rolling which contains cavities like those seen in the ingot from Pope & Cole. When this is rolled into a bar, the cavities will be extended in the direction of the length of the bar. When the pieces of bar are afterwards rolled into sheets, these cavities will also be extended in the direction of the width of the sheet. These changes in form would of course be irregular, and would tend to produce such shapes as were seen on the copper. These cavities would necessarily contain gas, and copper is a very excellent conductor of heat, while gases are as a rule very poor conductors. Then, when the whole is heated and allowed to cool, the space about the cavity would be longer in cooling than the remainder, and, as a consequence, more scale would be formed at that point than elsewhere, and might adhere more firmly, or its formation might continue after the scaling process was considered complete. This layer of oxide and cushion of gas would then prevent the copper at this point from becoming as hard, through rolling, as over the remainder of the surface. The fact that the copper appears slightly laminated at some of the corroded spots seems to substantiate this theory. It may be objected that an enclosed gas at the high temperature of the operation would exert pressure sufficient to burst the envelope, but we must remember that the cavities were formed when the gas was at the temperature of molten copper.

In conclusion, I would state that I find the source of corrosion of the Juniata's copper to be due principally to the presence of spots of oxide of copper on the surface of the plates, and I would recommend in the future the use of a pure copper, care in the production of sound cakes, and careful removal of the scale.

INLAND NAVIGATIONS IN EUROPE.

By Sir CHARLES A. HARTLEY, K.C.M.G., M. Inst. C. E.

A Lecture before the Institution of Civil Engineers.

II.

FRANCE.

My description of the chief rivers of France, so far as regards their navigable capabilities, must necessarily be very brief.

The Seine rises on the northern slope of the Côte d'or, at an elevation of 1,460 feet. Its length is 480 miles, and it first becomes navigable near Troyes, about 350 miles from it mouth. Its principal tributaries are the Yonne and Eure, on the left bank,, and the Marne and Oise on the right, and by means of waterways it communicates with the Loire, Saône, Rhine and Scheldt.

From Paris to Tankerville, at the head of the estuary, and 16 miles from Havre, the Seine is so winding in its course that whilst by water the distance is 220 miles, it is only 100 miles in a straight line. From Paris to Rouen, 150 miles by water, and only 72 in a straight line, the river is studded with many islands, and its average fall is 6 inches per mile. At Rouen the level of low water is only 10 feet above the sea. Until the end of last century the low-water depth of the Seine was only $2\frac{1}{2}$ feet, and for nearly fifty years afterwards it was considered to be in a good navigable state when giving a draught of 4 feet. Between 1846 and 1865 numerous locks and weirs were constructed between Paris and Rouen to provide a depth of 5 feet, but before the works were completed it was decided to increase the draught to $6\frac{1}{2}$ feet. The engineers, however, who were entrused with this work, seeing its inadequacy, proposed increasing the draught to $10\frac{1}{2}$ feet, so that vessels of 800 tons burden could come up to the Pont de la Concorde at Paris at all times, and the execution of a project with this end

in view was decreed in 1878. At the present time, between the first lock at Surenne and the last one at Martot—15½ miles above Rouen—there are seven locks, the average distance between them being 15¼ miles. The average rise of these nine locks is 8 feet 3 inches, the maximum at Martot being 13 feet 9 inches, and the minimum at Mericourt 6 feet 5 inches. The estimated cost of the improvements, which are still in progress, consisting principally of several new locks provided with movable weirs, is £1,700,000, including the provision of the same draught of water throughout the whole of Paris. At Bougival, 30 miles from Paris, the new lock is 722 feet long, and at Port Villez, 60 miles from Paris, the lock and weir, which together cost £235,000, were completed in 1880. The weir of this lock consists of two navigable passes 198 and 194 feet wide, and of an overfall 267 feet wide. Many interesting details concerning fixed and movable weirs in France will be found in Mr. Vernon-Harcourt's Paper on that subject.

The navigation of the Seine from Rouen to the sea (76 miles) is both tedious and difficult, owing to its very sinuous course and to the numerous shoals which obstruct the shifting channel of its estuary, and it is with the view of rectifying this latter evil that a canal is now being made between Tankerville and Havre, so that ultimately vessels navigating the Seine above Rouen may reach Havre with expedition and at small cost. The canal will be at one level throughout, and is to have a lock at each end 590 feet long and 98 feet wide. The depth of the canal will be 10½ feet (3.25 metres).

With regard to traffic on the Seine, it was stated in 1872 by Mr. Krantz that the canalized river between Paris and Rouen carried 150,000,000 ton-miles, or more than one-eighth at that time of the whole water traffic of France, and about one-twenty-fifth of that of all the railways.

The mean discharge of the Seine is 24,500 cubic feet per second from a total area of 30,000 square miles. The discharge at Paris at high floods is 60,000 cubic feet per second, and 1,230 cubic feet at extreme low water. During the extraordinary high flood of 1876 the water rose 25 feet 3 inches at Paris, and 13 feet 6 inches at Rouen.

The Loire rises in the Cévennes 30 miles from the course of the Rhone, and flows in a north-west and west direction through the centre of France to the Bay of Biscay. The mean discharge of the Loire is 34,800 cubic feet per second from an area of 44,000 square miles. Of its total length of 607 miles, 450 are navigable, but its chief tributaries, four on the left and one on the right bank, are of little service to the navigation, owing to their shallow and irregular channels. In the middle part of its course the Loire traverses some of the most beautful scenery in France. In the lower part, which is subject to frequent and sometimes disastrous inundations, high embankments have been thrown up to contain the floods, and a lateral canal was completed in 1838 between Roanne and St. Brisson to afford the means of navigation at all stages of the river. Of all French rivers the Loire is the most irregular in its *régime*, and therefore the most intractable as a navigable stream. Its bed, occasionally half filled for a day or two with sand-banks, intersected by serpentine channels, which are barely navigable for small river craft, becomes covered in a few days with from 20 to 24 feet of water. At such times the embankments are overtopped, many breaches are made in them, and the country is inundated far and wide. To give an idea of the great variations in the volume of water discharged by the Loire below the confluence of its chief tributary the Allier, I may state that, according to Mr. Reclus —to whom I am indebted for many of my figures concerning French rivers—the maximum discharge at floods is 353,000 cubic feet per second, and the minimum only 1,060; the mean being 10,600 cubic feet per second. Thus the extreme difference in the discharge of the Loire at the "bec d'allier" is from 1 to 330, or more than one-half greater than that of the river Ruhr, which, as has been already mentioned, is from 1 to 200.* The City of Nantes is the chief maritime port of the Loire, but owing to its shallowness

* Régime of the Lower Loire, after Comoy, 1856, in cubic feet per second:
Confluence of the Maine maximum discharge 215,145; minimum 4,485=1 to 47
Nantes maximum discharge, 215,980; minimum, 10,600=1 to 20

ocean steamers of deep draught are compelled to load and unload 30 miles lower down stream, either at St. Nazaire or at Paimbœuf, close to the river mouth.

The Garonne (615 miles in length) rises in the Pyrenees within the Spanish frontier, becomes navigable at Cazéres, is connected with the Mediterranean at Toulouse by a canal, and finally unites with the Dordogne about 13 miles below Bordeaux to form the large estuary of the Gironde, a tidal basin 50 miles long. The river frequently overflows its banks, and, owing to general shallowness and frequent changes in its bed, the inland navigation of the Garonne, and of its tributaries above Bordeaux, is subject to many difficulties, in spite of the generally successful results of the system of training works that has been adopted at several places, with the object of maintaining a depth of at least 7 feet in the artificially contracted channel without having recourse to dredging.

Vessels of 800 tons can trade to Bordeaux, but ships of larger burden can only ascend the Gironde as far as Pauillac on the left bank, about 30 miles below Bordeaux, and about the same distance from the Atlantic. The Gironde, which comprises the united waters of the Garonne and Dordogne, has a mean discharge of 41,000 cubic feet per second from an area of 35,000 square miles.

The Rhone (635 miles in length) has its source in Switzerland, not far from the St. Gothard Pass, and enters France by the narrow defile of l'Écluse. Its upper course is both rapid and tortuous, and hardly navigable, until Lyons is reached at the confluence of the Saône. The Saône from its course in the Vosges flows south-west and south, and possesses an excellent system of navigation for 170 miles, through the lower part of its highly fertile valley. The chief towns on its banks are Beaune, a little above which the Saône and the Seine are connected by the Canal of Bourgogne-Chalon, where the Canal du Centre joins the Saône with the Loire and Mâcon. In the 200 miles from Lyons to the Mediterranean the Rhone falls 532 feet, giving an average of 32 inches to the mile. Notwithstanding this great inclination, the river is navigable the whole way for vessels of considerable burden excepting at extreme low water, when the depth is less than 3 feet in many places, or barely enough for the working of the steam-tugs on the grapping system, which are in constant use above Arles, a large town at the head of the delta, and 175 miles from Lyons. The charge for up river transport between these two places is $\frac{1}{4}d.$ per ton per mile.

The Rhone has a mean discharge into the sea of 60,600 cubic feet per second from an area of 38,000 square miles. Its maximum discharge is 423,840 cubic feet per second, and its minimum 19,426 cubic feet = 1 to 22.

The improvement of the Rhone as far as Arles from the new Mulatière dam (525 feet long and 52½ feet wide) at the junction of the Rhone and the Saône,* so as to ensure everywhere a depth of 5 feet 3 inches (1.60 m.) at low water, is now in progress, and a grant of £1,800,000 has already been obtained for this work. The project is a combination of the two systems of regularization and canalization, and the cost of improving the navigation throughout on this principle is estimated by Mr. Pasqueau, the author of the project, at £2,250,000. Between Arles and the Mediterranean the minimum depth of the channel is about 6 feet, or as much as exists on any one of the bars at the mouth of the river.

To avoid these bars, after having tried unsuccessfully to deepen one of them by the system of parallel piers, which for want of being carried sufficiently far seaward never had a fair chance of success (although such a chance would have been but a feeble one if, as has been stated on good authority, there is no littoral current), the Government resorted to the expedient of cutting a lateral canal 2 miles in length, and furnished with a lock, from the tower of St. Louis to the neighboring Bay of Repose. By means of this work, the annual maintenance of which has not been onerous, vessels drawing up to 19 feet have been able to enter the Rhone since 1862, when the canal was completed at an expense of £620,000 including quays. As a work of art, the canal (which I visited more than once whilst under construction) reflects great credit on Mr. Pascal, Inspector-General

* Relative discharge of the two rivers at their confluence at Lyons, in cubic feet per second—

	Extreme low water.	Mean.	Extreme floods.	Proportion low to high.
Rhone....	8,630 ..	22,958 ..	211,920 ..	1 to 24
Saône....	2,119 ..	8,880 ..	141,280 ..	1 to 66

of Roads and Bridges, under whose direction the works were executed.

With regard to the condition of the Rhone as a navigable stream, Mr. Reclus stated in 1879, that "before the construction of the Lyons and Marseilles Railway, the navigation was very important, but that since that time it has never been able to compete with the railway; in place of sixty-two steamers, which were always employed in carrying goods from one port to another, there are now only eight boats employed in carrying an annual freight of little more than 200,000 tons."

With but few exceptions, the earliest of the canals in France were laid out solely with reference to local interests, and were therefore as a rule, badly adapted for economical transport over very long distances. On the other hand, since 1821–22 when the most important canals of the country were designed, and their execution decreed, French waterways have been dug down to a uniform depth of 5 feet 3 inches (1.60 metre) over a bottom width of 33 feet (10 metres), with the view of giving the cheapest and most direct means of transit between great centres of trade far apart from each other. In the north, the Seine is placed in direct communication with Belgium, by the river Oise which the canal of St. Quentin prolongs to Mons, and the canal of Charleroi to the town of that name. On the other hand, the canal of Ardennes unites the basin of the Seine with that of the Meuse, and consequently again puts it in communication with Belgium and Holland. In the west, a network of canals, commencing at Nantes, puts Brittany in direct intercourse with the naval ports of Brest and L'Orient; and, by the Loire, with the centre of France. In the East, Paris is in direct communication with Nancy and Strasburg by the Marne and Rhine Canals. In the south, the lateral canal of the Garonne and the Canal du Midi unite the Atlantic with the Mediterranean and Bordeaux with Cette. This latter port is also in direct communication with the Rhone by means of canals to Aigues Mortes, and Beaucaire.

The celebrated canal of Languedoc, now an integral part of the Canal du Midi, was built in 1667–81 (eighty years before the opening of Brindley's Bridgewater Canal) by Riquet, the greatest engineer of his day. It has a length of 171 miles and a depth of 5 feet 3 inches, and its highest part is 600 feet above the sea. From this summit level it communicates with the Garonne, and therefore with the Atlantic, by twenty-six locks, and descends the southern slope by seventy-three locks to the Mediterranean.

With reference to the Canal du Midi, I have the authority of Mr. Malézieux, Inspector-General of Roads and Bridges, for stating that, like all the canals in France classed as principal lines of communication by the law of 1879, it is to be deepened to 7 feet 4 inches (2.20 metres) or its level is to be raised in such a way that vessels drawing 6 feet 6 inches (2 metres) may be able to navigate through it without delay. The same decree also prescribes that the locks of all the principal canals shall have a clear length of 126 feet (38.50 metres) and a width of 17 feet (5.20 metres) with sufficient water on their sills (now fixed at 2.50 metres) to allow the free passage of vessels drawing 6 feet 6 inches (2 metres).

According to the returns of Mr. Krantz, member of the National Assembly for inquiring into Internal Navigation in 1872, the length, cost of construction, and of transport were then as follows:—

Total length 8,120 miles, of which 3,123 miles were canals, and 4,997 rivers.*

Cost of construction £46,295,837, of which £32,738,715 for canals, and £13,557,152 for rivers.

Cost of transport with tolls, 0.324*d.* per ton per mile for canals, and 0.410*d.* for rivers.

Ibid., without tolls, 0.243*d.* per ton per mile for canals, and 0.324*d.* for rivers.

To complete Mr. Krantz's information and to bring the mileage of French waterways, already made and still to make, down to a later date, I quote the following from a tabular statment by Mr. Conder.

	Miles open in 1878.	Miles to open.
Basin of the Seine	1,582	233
" Rhone	994	201
" Loire	1,979	774
" Garonne	1,324	328
" Gulf of Gascony.	272	162
Channel and North Sea	576	59
Charente and Sèvre Niortaise.	342	56
Total open and to open	7,069	1,813

Grand total, 8,882 miles.

Total cost of 7,039 miles of waterways, £43,608,516.

* Mr. Krantz remarks that "the 'rivers' includ[illegible]

From the foregoing, it would appear that in 1878 France had spent considerably more than double the sum spent by the United Kingdom (£19,145,866) up to 1844 in the improvement of inland navigations. Nevertheless, comparatively large as had been her expenditure in this regard up to 1878, a Bill was deposited in that year in the Chamber of Deputies for still further systematizing and improving the internal navigation at an estimated cost of £40,000,000.

From the "Bulletin des Travaux Publics, 1881," an interesting comparison has been made by Mr. Petit, concerning the three great trade routes in France. Mr. Petit's résumé is as follows:—

Transit Routes.	Length.	Tonnage.		Proportion of Tonnage.
		Mean.	Kilometric.	
	Kilometres. (Miles.)			Kilo.
Railways.....	24,383 (15,141)	415,394	10,801,259,457	75
Navigable rivers.....	11,986 (7,432)	182,000	2,174,531,000	15
Highways.....	37,462 (23,264)	39,400	1,480,148,000	10
Total.....	37,813 (45,827)	196,000	14,455,938,457	100

This Table shows that although in 1880 the length of inland navigations was one-half that of railways, the amount of traffic carried by them was only one-fifth. On the other hand, taking the cost of railways at £30,000 per mile, and £6.000 as that of canals as capital, and the figures 415,394 and 182,000 in the above Table as representing traffic, the contrast is evidently and strikingly in favor of canals even in their unimproved state.

The total length of French railways in 1884 was 16,886 miles, as compared with 5,262 miles in 1860, being an increase of 320 per cent. in the last twenty-four years.

SPAIN AND PORTUGAL.

The chief rivers of the Iberian Peninsula are eight in number. Five of them, the Minho, Douro, Tagus, Guadiana, and Guadalquiver, drain the western valleys, and flow into the Atlantic; and the other three, the Ebro, Jucar, and Segura, drain the eastern valleys, and discharge their waters into the Mediterranean. The high mountain ridges and elevated plateaux which Spanish rivers have to descend give them a rapid course, so that in general they are of comparatively little use for navigable purposes, and running, as they often do, in very deep beds, are frequently unavailable for purposes of irrigation.

The Tagus drains an area of 37,500 square miles. Taking its rise on the borders of Aragon and Castille, it dashes down to the plain of Zarita, and thence, flowing tranquilly through the Royal Gardens at Aranjuez, at an elevation of 1,700 feet above the sea, passes with quickened velocity the old walls of Toledo, Talavera, Alcantara, and Abrantes, and finally, after a course of 570 miles from its source, empties itself into the Atlantic, about 7 miles below Lisbon. Unfortunately for commerce, the Tagus is only navigable to the Portuguese frontier, or about 120 miles from the sea. Opposite Lisbon, on the south shore, is Cassilhas Point, or the eastern extremity of what may be called the Port of Lisbon, whence a wide expanse towards the north opens out into a magnificent harbor, of from 2 to 7 miles in breadth. At the Point itself the river is 1 mile wide, but it narrows to ¾ mile at Belem, on the north bank 2 miles below Lisbon, whence it expands again to a width of nearly 2 miles at its mouth. The bar has a depth of from 6 to 7 fathoms at low water of spring

this statement are not all strictly navigable, and that the length of those portions which are suitable for navigation does not exceed 5,700 kilometres" (3,554 miles).

tides, and the channel within it soon deepens to 19 fathoms. Notwithstanding this great depth, however, the bar is impracticable in south-westerly gales, and in winter, or when the freshets are strong and accompanied with westerly gales, continues so for several days together.

The Douro is 485 miles long, and drains an area of 37,000 square miles. Its direction is generally west, and it traverses the most mountainous portions of Leon and Salamanca before it reaches the Portuguese frontier. Thence to the sea, the channel is everywhere narrow, with a rocky bed, and the water, being confined, the current frequently exceeds 9 miles an hour at times of thaw and heavy rains. Instances have already been given of great oscillations in the volume of discharge in the rivers Ruhr and Loire, but these may be termed insignificant when compared with the variations in the volume of the Douro. On one occasion, in 1860, when the river rose to the level of 33 feet 9 inches above low water of spring tides at the suspension bridge, 3½ miles from the sea, the velocity equalled 16 knots an hour, and the discharge 995,000 cubic feet per second, or two and a half times as great as the highest flood-discharge of the Tagus. At the same bridge, and according to the same authority, Mr. A. J. Nogueira Soares, the lowest discharge in the summer months of 1875 was only 700 cubic feet per second.

Mr. Soares, in stating these phenomena, is justified, therefore, in declaring that there is probably no other river of importance where so great a flood-rise takes place so near the sea, or where the volume of fresh-water discharge varies from 1 to 1,500. During spring tides, he adds, the total tidal outflow does not exceed 35,300 cubic feet per second, or about one-thirtieth part of a great river flood.

The depth of water on the bar of the Douro, between the years 1874–78, averaged 14 feet 6 inches at low water, or 25 feet 6 inches at high water of spring tides. Oporto, the second city of Portugal, stands on the side of a steep eminence of about 200 feet elevation, which rises from the north bank of the Douro about 2 miles from the sea. The river is navigable for 70 miles from the entrance, and boats of light draught can proceed 30 miles higher. Grain and other produce are floated down from Spain on flats, but navigation is often interrupted by heavy floods.

Guadalquiver rises on the borders of Murcia, drains 22,000 square miles, has a length of 375 miles, and occupies the centre of the plain that lies between the Sierra Morena and the chain of Granada. In the upper part of its course it intersects the rich province of Andalusia, and after pursuing its way through pestiferous swamps to Cordova and Seville at last forms a harbor near its mouth, above the seaport of San Luca de Barrameda, whence Columbus sailed on his third voyage to America in 1498, and Magellan on the first voyage of the circumnavigation of the world in 1519. The Guadalquiver is navigable for vessels of 100 tons at certain seasons of the year, up to Seville, 70 miles from the sea, but, as a rule, vessels of more than 10 feet draught are obliged to load and unload about 8 miles below the city. The channels between the shoals at the mouth of the river are only practicable for small vessels.

The Guadiana rises in La Mancha, and after passing through the province of that name, flows on to Merida and Badajos. A little below the latter it turns to the south and enters Portugal, through which it flows for nearly 100 miles, and then, again washing the frontier of Spain, forms the boundary of the two kingdoms to the sea. The area of the basins of the Guadiana is 25,000 square miles. Although 316 miles in length, the river is only navigable up to the town of Mertola, about 40 miles from its mouth at Villa Real. The entrance to the Guadiana is encumbered with shoals, and at low water there is only a depth of about 6 feet on the bar, or 18 feet at spring tides. Within the bar, however, off Villa Real, where the river is ½ mile broad, the depth is 27 feet.

The Ebro rises in the province of Santander, and drains 39,000 square miles, and after a course of about 470 miles, empties itself in the Mediterranean, about 15 miles east of the town of San Carlos de la Rapita. It receives one hundred and fifty tributaries, and its chief towns are Tudela, Saragossa, and Tortosa. At Amposta, 20 miles below Tortosa, the river divides and runs into the sea by two branches. In order to facilitate the

communication with the sea, a lateral canal, 10 miles long and 5 feet deep, runs south from Amposta to San Carlos, at Port Alfaques, where there is room for a large number of vessels not drawing more than 18 feet. The principal commercial utility of the Ebro is the transport of grain from Saragossa to Tortosa, together with the floating down of timber from the Pyrenees. Owing to the shallow channels of the Delta, however, and to the numerous sandbanks at its mouths, only vessels of very light draught are able to pass the bars, and hence the navigation of the Ebro, although the largest river in the peninsula, is not very important. As a source of supply for irrigation, however, the Ebro, like the majority of Spanish rivers, is of more value in this respect than as a navigable stream. Its bed is rocky, and its current above the influx of the Segre, its principal affluent on the left, much disturbed by rapids and cataracts: and though this evil has been remedied in part by the construction of a navigable channel, the Imperial Canal from Tudela to a point 20 miles below Saragossa, yet the obstacles to navigation are still great; and whilst its use as a source of supply for irrigation is increasing, its volume for navigable purposes goes on decreasing in the same degree.

Besides the navigable canals connected with the Ebro, there are only worthy of special mention the canal of Segovia, connecting that town with the river of the same name, and the canal of Castille, to unite Santander with the Douro, a work, however, which is only partly finished. According to Millet, the total length of navigable canals in Spain was only 130 miles in 1875. On the other hand, the length of her railways was 5,600 miles in 1884.

ITALY.

Italy is not rich in waterways except in the valley of the Po. The navigable portions of her rivers—the most important of which will shortly be described—have only an aggregate length of 1,100 miles.

The Po rises at 6,560 feet above the sea, and in a course of 350 miles drains an area of 29,000 square miles. At a distance of 20 miles from its source it enters the plain of Saluzzo, between which and Turin, a distance of only 30 miles, it receives three considerable tributaries. The Dora, which flows past Susa at the foot of Mont Cenis, unites with the greater river a little below Turin, and the Sesia joins it 25 miles below the confluence of the Dora. About 30 miles still further on, the Po is joined by the Ticino, which brings with it the overflow of Lake Maggiore. Its next great affluent is the Adda, which flows through Lake Como; then comes the Oglio from Lake Iseo; and finally the Mincio runs in near Mantua from Lake Garda. At its confluence with the Mincio, the Po has a width of from 1,200 to 1,800 feet, and it then continues to flow on in an undivided stream to its first bifurcation near Ponte Lagoscuro, and thence on to Maria de Ariano—about 25 miles from the sea—where it parts into two arms, and these again are subdivided into several other branches, forming an extensive delta about 20 miles in width from north to south. The growth of the delta since the time of the Romans is very marked. The town of Adria, which was then a maritime town, now stands on the banks of the Po 20 miles inland, and it has been estimated that from the year 1600 to 1800, the delta advanced at the rate of 225 feet annually. On the other hand, to the north of the delta, there is equally good evidence of the encroachment of the sea on the land.

The Po is continuously embanked from near Cremona to the marshes at its mouths. At its highest flood the water rises 24 feet above extreme low water at the confluence of the Ticino; 26 feet near Piacenza; 20 feet at Cremona; and 28 feet at Ponte Lagoscuro, 4 miles above Ferrara, where the level of low water is only 9 feet above the sea, from which the old city is now removed 50 miles, or 20 miles further from the coast than two thousand years ago. Hence it is that the top of the embankments at Ferrara is higher than the roofs of the houses. The prevention of the lateral spread of the water in floods by dykes is said by many engineers to occasion the deposit of sediment in the channel, and consequently to cause an elevation of the bed, which requires the embankments to be raised proportionally; but Lombardini has shown that the effect of this on the Po is by no means so considerable as has been

often represented, and that in the middle lower course of the river the bed of the proper low-water channel is subject to so little permanent change of level as to have now become substantially constant.

The mean discharge of the Po is 60,745 cubic feet per second, its maximum 181,580, and its minimum 7,558 cubic feet per second, or a ratio of 1 to 24. The waters of the Po are very heavily charged with detritus, and according to Mr. Boccardo, the volume held in suspension is at times $\frac{1}{300}$ of the volume of water discharged.

The Po is navigable from its mouth for vessels of 130 tons up to Valenza, 600 feet above the level of the sea, and 7 miles below the confluence of the Sesia, and below the confluence of the Oglio the depth of the main river at extreme low water is never less than 5 feet 10 inches; but as most of the transport which would otherwise be carried on by means of its channel is now effected by railways, of which Italy possessed 5,651 miles in 1883, the river has lost much of its relative importance as a route for commercial communication.

The Adige rises in the Tyrolean Alps, and drains 5,400 square miles in a length of 234 miles. Flowing southward it passes by Trent, and enters Lombardy. After passing Verona, it flows nearly south-east, and pursues a course parallel to that of the Po till it enters the Adriatic by an independent mouth about 13 miles north-east of Adria. The waters of the two rivers have been made to communicate by artificial cuts at several places. The Adige is navigable from its mouth to Trent, but the velocity of the current impedes the navigation.

The Tiber rises in the Apennines at a height of 3,805 feet above the sea, and drains 6,500 square miles, and after a course of 240 miles, generally in a south direction, empties itself into the Mediterranean through two mouths about 16 miles south-west of Rome or 24 miles by the course of the river. The mean discharge of the Tiber is 10,800 cubic feet per second, and its minimum discharge 5,800 cubic feet per second.*

Rozet has calculated that the advance of the delta for many centuries past has kept steadily at the rate of 13 feet per year. The estuary, which originally formed the harbor of Rome, was so reduced in depth by silt from the river and sand rolled in by the sea, that it was found necessary in the days of the Empire to cut a channel from a point about 1½ mile above Ostia (the ancient sea-port of Rome, and now 2½ miles inland) to the coast, at a place called Fiumicino, situated at 2 miles N. of the chief disemboguement of the Tiber, now called the Bocca di Fiumara. The artificial canal—known as the Fiumicino branch—(on the north bank of which are the remains of the once famous ports of Claudius and Trajan) is still the only navigable channel between the Mediterranean and Rome, the old Fiumara mouth being obstructed by constantly-shifting sandbanks.

The rise of the Tiber in its great floods is very considerable, and is measured from the zero of the hydrometer at the Ripetta stairs at Rome. This zero is 4 feet above the level of the sea. The lowest known surface of the Tiber at the stairs is 17½ feet above zero, and its mean height 22 feet. In the inundation of 1870 when I was on a visit to Rome, the waters rose to 56 feet 6 inches above zero, and as the pavement of the Ripetta and that of the adjacent streets is only about 44 feet above zero, all the north-west quarter of the city, including the Corso and other important business streets, was overflowed, to a depth near the river of about 12½ feet, and the direct and indirect damage occasioned by the flood, which was the greatest on record since 1637, could hardly be over-estimated. Numerous schemes have since been proposed to prevent the recurrence of a similar disaster. Grave objections have been made to many of these projects, but on one point all engineers seem to agree—and this principle is now being practically carried out—the expediency of widening and straightening the channel at various points within and near the limits of the city, of carefully regulating the outflow of drains into the river, and of removing from its bed the numerous artificial obstructions, chiefly piers of old bridges, and accumulated rubbish of centuries.

The Tiber is navigable from the sea to

* The proportion of the minimum to the maximum flood has been variously estimated by Italian engineers as being from 1 to 25 to 1 to 30; or from a minimum discharge of 3,500 cubic feet per second to a maximum of 105,000 cubic feet. According to Mr. Vescovali, the discharge of the Tiber has never been less than from 5,600 to 6,300 cubic feet per second.

Rome for vessels of 140 tons, and, with some difficulty, 60 to 70 miles further for vessels of 60 tons. At the Fiumicino mouth of the river the entrance is narrowed between parallel piers so as to increase the scour over the bar, but the available depth on it is rarely more than from 6 to 8 feet.

The Italians were the first people in Modern Europe who attempted to plan and execute canals. As a rule, however, they have been principally undertaken for the purpose of irrigation. The total length of the navigable canals is 435 miles. The most important are the Canal Cavour, in Piedmont, which, supplied from the Po, begins at Chivasso and terminates at Turbiga, a distance of 52 miles; the Grand Canal, in Lombardy, supplied from the Ticino, near Tornaveno; the Canal of Pavia, also supplied from the Ticino, and passing through Binasco; the Canal of Martesana, which, from Milan through Gorgonzola, leads to Cassano on the Adda. The provinces of Polesina in Venice, of Padua, and the Emilia have all excellent canal systems. In Tuscany the most important are those of Pescia, Pisa, and Ombrone.

AUSTRIA-HUNGARY.

As the highlands of Austria form part of the great watershed of Europe which divides the waters flowing north into the North Sea or Baltic, from those running south or east into the Mediterranean or the Black Sea, all Austrian rivers of note flow either north, south or east. All her great river mouths, moreover, are situated in other countries, and one of them, the Danube, has its source as well in a neighboring State. The courses of its chief streams, namely the Dnieper, the Vistula, the Oder, and the Elbe, have already been summarily passed in review, and it therefore only now remains for me to describe the course of the Danube to complete the list.

THE DANUBE.

The Danube is the largest river in Europe as regards volume of discharge, but is inferior to the Volga in the length of its course and the area of its basin. It rises in the Black Forest at an elevation of about 3,600 feet above the sea, and drains 316,000 square miles, its total length being 1,750 miles.

From the mouth of the Iller, which divides Würtemburg and Bavaria, the Danube is fed by at least three hundred tributaries. On the right bank, the chief of these, with their drainage area in square miles, are: the Inn (9,600), the Drave (14,300), and the Save (37,500), and on the left bank the Theiss (60,000), the Olta (9,000), the Sereth (18,000), and the Pruth (10,000). Together, these seven streams have a length of 2,900 miles and drain one-half of the whole extent of the Danube basin.

UPPER AND MIDDLE DANUBE.

The upper part of the river first becomes navigable, for flat bottomed boats carrying 100 tons, at Ulm, 130 miles from its source, and only a few miles below the confluence of the Iller, its first tributary of any importance.

At Kelheim, half way between Ulm and Passau, the Danube communicates with the Rhine by means of the Ludwig Canal, and the rivers Altmühl, Regnitz and Main. The canal is 110 miles long and 7 feet deep, and was completed in 1844 by King Ludwig the First of Bavaria. From Ulm to Passau (220 miles), at the mouth of the river Inn, which doubles the volume of the main stream, the Danube traverses the great Bavarian plain, but thenceforward it flows through a mountainous region till it reaches Vienna. In this distance of 406 miles of the lower section of the Upper Danube the river has been considerably improved by works of correction, and vessels drawing 4 feet can now navigate the whole distance at low water, excepting at the Fischament-Theben rapids, where the depth is occasionally reduced to 3 feet.

At Vienna, which is situated on the right and left banks of a branch of the Danube (164 feet wide and 4 feet deep at low water) at an elevation of about 520 feet above the sea, and at a distance of 1,208 miles from the Sulina mouth, the main stream of the river has been brought 1½ mile nearer to the city by a new channel 10 miles long, 1000 feet wide and with a depth of from 10 to 12 feet below ordinary low-water level. This great cut involved the removal of 12,000,000 cubic metres of sand and gravel, and, with all its subsidiary work, cost £3,250,000. The enterprise was established by an Imperial Commission in 1866, and the

proposal to construct the regulation on its present plan had the able support of Mr. James Abernethy, Past-President Inst. C.E.

The cutting has been very successfully carried out, and has already been of great service, not only in protecting Vienna from disastrous floods, the principal object of the scheme, but in improving the railway communications and the navigable capabilities of the river at this portion of its course.

Further particulars of this interesting river diversion, written by the Engineer-in-Chief, Herr Von Wex, are published in our Abstracts of Papers in Foreign Transactions.

The construction of a deep canal, about 150 miles long, from a point on the left bank about 6 miles below Vienna, to Oderburg on the river Oder, has lately been under serious consideration, and the execution of this project bids fair to become an accomplished fact at no distant day.

From Vienna the Danube flows east for 150 miles through a wide expanse of plain country to Waitzen; and then turning south pursues that direction through the great plain of Hungary by numerous windings to Esseg situated at the confluence of the Drave, 347 miles below Vienna, and 165 miles below Buda Pesth. This imposing-looking capital of Hungary is situated on the right and left banks of the Danube at 182 miles below Vienna, 152 below the confluence of the March at Theben, the frontier of Austria-Hungary on the left bank; 146 from Pressburg; 89 from Gönyö near the confluence of the Raab; and 21 from Waitzen. From Esseg the river trends south-east to Semlin (140 miles), the lower frontier town of Hungary on the right bank at the confluence of the Save, and immediately opposite Belgrade, the capital of Servia. Hence to Old Moldova (76 miles), and then on to the Hungarian-Roumanian frontier at Old Orsova (63 miles) the river flows nearly due east. At Old Moldova, it enters a series of rocky gorges, unequalled in Europe for their grandeur; and after sweeping through a succession of deep pools and shallow rapids, confined within the grand passes of Stenka, Izlaz, and the Kasan, finally reaches its last and most formidable rapid called the "Iron Gates," 632 miles from Vienna, and 582 miles from the Black Sea.

Although the Danube, from Vienna to Old Moldova, has also been regulated in numerous places and at great cost, by narrowing and training works, consisting of groynes, dams, and longitudinal dykes, there has been but little appreciable improvement effected in its general navigable depth. On this account, projects, having in view the permanent acquisition of a sufficiently wide channel of from 6 to 8 feet deep at every point between Passau and Old Moldova, have lately been prepared by Government Engineers, which involve an outlay of £2,000,000 to effect the desired improvements, the principal of which would be the permanent removal of the Fischament-Theben, and the Pressburg-Gönyö shoals.

With the exception of a short stretch of the river near Gonyo, the existing channel between Vienna and Old Moldova, affords a minimum depth of from 4 to 5 feet, during nearly two-thirds of the year (taking the ice into consideration); but at Gonyo itself, the navigation during the dry season is so difficult that a depth of from 3 to 5 feet is only maintained by Mr. Murray Jackson's excellent system of steam-raking, a full account of which will be found in our Minutes of Proceedings.

The Danube between Old Moldova and the Iron Gates (69 miles), 6 miles below Orsova, the frontier town of Hungary, is traversed at eight different places by reefs of sharp-pointed rocks, which render the navigation difficult at ordinary low water, and altogether impracticable at the lowest water season. These serious natural obstructions have hitherto been the great barrier to the free development of traffic on the middle and lower Danube, and the existing slackness of trade at this part of the river will continue, and possibly increase, until its navigable condition has been radically improved. These so-called Cataracts of the Iron Gates, which are wholly within the territories of Roumania and Servia, have a length of 5,070 feet, with inclinations of 1 in 507 at high, and 1 in 307 at low, water; the extreme variations between high and low water being 14 feet 6 inches at the head and 22 feet 6 inches at the foot of the falls. The level of low water at Old Moldova is 201 feet, and at the foot of the Iron Gates,

118 feet above sea-level. This fall of 83 feet in 69 miles gives an inclination of 1 in 4,400, as compared with 1 in 2,220 between Passau and Vienna, and of 1 in 10,000 between Vienna and Old Moldova.

For more than a quarter of a century projects have been made for surmounting the difficulties between Old Moldova and the foot of the Iron Gates, by four different systems of treatment, namely, by open cuts; by simply narrowing the channel; by excavated channels confined within submerged and insubmergible walls; and by a combination of one or more of these plans, aided by one or more lateral canals.

The latest project is that of an International Commission of Engineers named by the Austro-Hungarian Government in 1879. This Commission proposed to establish a channel 2 metres deep at extreme low water, at every point between Old Moldova and Turn-Severin by means of cutting 60 metres wide through the upper seven shoals, and to construct a lateral canal at the Iron Gates on the Servian shore, provided with two lift locks (508 feet by 118 feet) to overcome a difference of level of 14 feet 6 inches at that place. The cost of the open cuttings was estimated at £350,000; the improvement of the Iron Gates at £530,000.

The width of the Danube between Vienna and Basias (15 miles above Old Moldova) varies from 2,000 to 6,000 feet at low water, and from 7 miles to 30 miles at high water; but to this statement exception should be made of Peterwardein (50 miles above Belgrade), where the entire volume of the river, at high and low water, flows through a channel 40 feet deep, and only 800 feet in width. At this spot, 777 miles from the Black Sea, the Danube is crossed for the last time by a railway bridge, or, indeed, by a bridge of any kind whatever. At the Kasan, a pass 5½ miles long, where the granite cliffs rise to a perpendicular height of nearly 1,000 feet, and where the depth is 80 feet in the dry season, the main width of the river is but 600 feet, and the difference between extreme high and low-water level as much as 23 feet. The mean velocity of the current from Vienna to Basias is 2 knots an hour, and 3 knots at high water, but at the narrow defiles of the Kasan and Izlas it attains 8 knots at high floods.

The Hungarian central section of the river is fed by the Drave, the Theiss, and the Save.

With regard to the Save and the Drave, I have only time to remark that their improvement has never yet been attempted; that the former is navigable in its natural state to the confluence of the Mur (150 miles), and the latter to Sissek (370 miles), and that their lengths from their sources in Illyria to Esseg and Belgrade are 434 and 535 miles respectively.

The Theiss, or Tisza, falls into the Danube on the left bank, between Peterwardein and the confluence of the Save, and is navigable for a length of 475 miles to Tokay. It would require the time allotted for a whole lecture to give anything like a detailed description of this remarkable affluent, and therefore, in the few minutes at my disposal, I can only sketch its chief characteristics in the briefest possible manner. It rises in the Carpathians, and its basin drains one-fifth of the great valley of the Danube. Half a century ago it had a total course of 828 miles, and from Tisza Uylek, where it ceases to be a mountain stream, and enters the great Hungarian plain, a course of 750 miles. The length of its valley from Tisza Uylek is only 372 miles, so that, like the lower Seine, its length was double that of the plain through which it flowed. From Tisza Uylek to Szegedin (621 miles) the fall was 136 feet in 621 miles, or 1 in 24,500; and from Szegedin to the mouth of the river, 129 miles, only 8 feet, or 1 in 73,000. Between 1832 and 1879 the cut-offs executed by the Government for the principal purpose of protecting the adjacent lands from inundations, were one hundred and thirteen in number, of an aggregate length of 83 miles. These cuts shortened the river 300 miles below Tisza Uylek, and cost £690,000, exclusive of a further sum of £2,000,000, which was spent by local companies on 1,000 miles of embankments. According to the report of Mr. Herrich, Ministerial Councillor, the result of these great works has been to protect an area of 4,200 square miles, out of a total area of 6,000 square miles of low ground, from floods; but from no authority can I glean any information concerning the effect of the cut-offs on the navigable condition of the

river. Unfortunately, however, one fact is but too well known, namely, the great disaster of 1879, when the large town of Szegedin, at the confluence of the river Maros, was almost totally destroyed, and many of its inhabitants swept away by an unprecedentedly heavy flood. It should be added that the Maros enters the Theiss at a bad angle, and has also been greatly reduced in length—from 430 miles to its present length of only 162 miles.

The two chief canals in Hungary are the Bega, 75 miles long, joining Temesvar with the Theiss at Tetel, a little above its junction with the Danube, and the Franz Josef, 69 miles long, which stretches from the Danube at Battina by Zombor to the Theiss near Foldvar. On the latter canal the traffic increased from 246,000 ton-miles in 1876 to 600,000 ton-miles in 1878, but it has never yet, I learn, paid any interest to its shareholders.

According to Mr. Lanfranconi, whose Papers on Hungarian rivers, with excellent maps thereof, may be referred to with advantage in our library, Austria-Hungary possesses 2,104 miles of waterways made up as follows:

	Miles.
Passau to Orsova	817
Drave, Theiss and Save	1,013
Raab and Inn	48
Canals	226
	2,104*

Traffic on the upper and lower Danube is mostly carried in barges belonging to the Imperial and Royal Danube Steam Navigation Company, of which they possess about eight hundred, the greater portion having a carrying power of 250 tons. The mean annual traffic up-stream from Belgrade to Pesth is 600,000 tons, or about as much as by rail. The barges have been built in recent years entirely of steel, and have generally a length of 180 to 190 feet, with 24 feet beam and 8½ feet depth, and their displacement is 120 tons without cargo. The largest steamers are from 220 to 250 feet in length, with from 25 to 27½ feet beam and 10 feet deep at the sides, with a slight displacement of 440 to 460 tons.

Haulage is performed on the upper and central Danube by steam-tugs and chain-tugs; and it was with the view of obtaining some authentic information on this important subject that I applied some time ago to Mr. Murray Jackson, late Chief Engineer of the Danube Steam Navigation Company, for a short statement of the result of his long and varied experience regarding the relative merits of each mode of traction. Mr. Jackson has obligingly furnished me with some valuable "Notes" on "Water Traction by Steam Power," which are too long to repeat at this advanced hour; but I trust the Council will permit them to appear hereafter in the shape of an Appendix to my lecture, should the latter be considered worthy of publication.

* The total length of railways open for traffic in Austria-Hungary in January, 1884, was 12,223 miles.

LOWER DANUBE.

The Lower Danube begins at the foot of the Iron Gates, and terminates in the Black Sea, from which it is distant 340 miles in a straight line,, and 580 by the windings of the river. The left bank from Verciorova, the Roumanian frontier town (2½ miles from the Hungarian frontier town of Orsova) to mid-channel of the Pruth (11 miles below Galatz), is Roumanian territory; and from mid-channel of the Danube, opposite the mouth of the Pruth, the frontier of Roumania is conterminous with that of Russia (according to the Treaty of Berlin of 1878) to mid-channel of the Danube at Ismail Chatal, and thence to mid-channel of the Kilia branch at Wilkov, where the Kilia branch spreads out into several subsidiary channels. From the village of Wilkov the frontier follows the mid-channel of the Stary Stamboul, the most southerly of the branches of the Kilia delta, till it reaches the sea, at a distance of about 10 miles north of Sulina. The right bank of the river from the confluence of the Save at Belgrade to the mouth of the Timok at Rakovitza (59 miles below the Iron Gates) is in Servia; from Raovitzak to Silistria (284 miles) it is in Bulgaria, and thence to the sea, following the St. George's branch, in Roumania. Thus, both banks below Silistria belong to the Roumanians, with the exception of the left bank from the mouth of the Pruth to Wilkov, and thence to the sea by the Stary Stamboul branch. The fall of the river from the Iron Gates to Sulina gradually becomes less, as in the lower part of all large rivers flowing through their own alluvium as it reaches

the sea. Thus, between the Iron Gates and Tchernavoda, 388 miles, with a difference of level of 103 feet 6 inches, the inclination is 1 in 19,800; between Tchernavoda and Ibraila, 76 miles, with a difference of 11 feet, 1 in 36,500; whilst between Ibraila and Sulina, 116 miles, with a difference of only 3 feet 6 inches, it is reduced to 1 in 175,000.

1. IRON GATES TO IBRAILA.

At the Roumanian town of Turn-Severin, on the left bank, 8 miles below the Iron Gates, are still to be seen, at extreme low water, thirteen of the twenty stone piers of a bridge that was built across the Danube in A. D. 103, by Apollodorus, the architect who built Trajan's column at Rome. The river here is about 3,000 feet wide, and the maximum depth 18 feet. From Turn Severin to Widin, 83 miles, its course is very tortuous, but the general direction is to the south. From Widin, however, to Tchernavoda, 297 miles, its general trend is to the east. The river leaves the mountains behind at Widin, whence to Ibraila, the left bank is everywhere flat and uninteresting. The right bank, on the contrary, is bordered by high banks, as a rule, to the sea, and generally presents a landscape pleasantly varied by headlands, gentle slopes, and cultivated enclosures. Nicopoli, 122 miles below Widin; Sistov, 25 miles below Nicopoli; Rustchuk, 37 miles below Sistov; and Silistria, 68 miles below Rustchuk, all situated on considerable elevations on the right bank, and all famous as great battle-fields between the Russians and Turks, have each corresponding towns on the opposite bank, but the only one worthy of special notice is Giurgevo, the Port of Bucharest, and formerly the *tête du pont* of Rustschuk.

At Tchernavoda, 45 miles below Silistria, the width of the main river is 2,000 feet, and its depth at low water 28 feet. The extreme variation between high and low water is 23 feet, the latter having here a level of 14 feet 6 inches above the sea. When the floods attain a height of 18 feet the whole country is inundated (for the river below the Iron Gates is nowhere embanked), and its width expands across the Balta or island to the village of Fetesci, 8½ miles, to the high left bank of a subsidiary branch of the river, called the Borçea, which, leaving the Danube opposite Silistria, again joins the main stream 31 miles below Tchernavoda. Elaborate competition projects, presented by Belgian, French, German and Swiss engineers, have for some time past been under the consideration of the Roumanian Government for bridging the Borçea at Fetesci, and the main river at Tchernavoda, which was surveyed under my direction in 1882, so as to join Bucharest with Kustendjie, but although two of these projects were considered worthy of high commendation, no decision has yet been come to as to the precise dimensions of the structures to be erected.

The Danube at Tchernavoda, 210 miles from Sulina, is separated from the port of Kustendjie on the Black Sea by an isthmus only 40 miles wide, and if a waterway were cut to that seaport in the line of the existing railway at Trajan's Wall the distance by water from Tchernavoda to Constantinople would be shortened 263 miles; the distance from Sulina to Constantinople being 311 miles, and from Kustendjie to Constantinople only 218 miles. In 1837 surveys were made and a series of levels taken of this part of the Dobruja, with the view of constructing a canal across the isthmus, but the scheme was abandoned on ascertaining that the summit level was 164 ft. above the sea, and that no adequate supply of water could be obtained from the neighboring high lands to fill the locks that would be required to overcome the difficulties of the ground between the river and the sea. In 1854 an English company obtained a concession from the Sublime Porte to construct a railway instead of a canal, and in 1860 the Tchernavoda Kustendjie Railway was open for public traffic. Although well managed, it never prospered, owing to the impossibility of competing successfully with the Sulina route in its improved condition, and in 1882 the line was sold to the Roumanian Government, and it is now worked by the State. It may here be added that in 1884 the length of railways in Roumania already constructed was 850 miles, and the length under construction 340 miles. The charge of the railway for grain discharged from up-river craft at Tchernavoda, then cleaned by machinery and loaded into wagons, and finally shipped at Kustendjie, after

being transported over 40 miles of railway, has generally been 4s. per ton—a charge by no means excessive—and yet, with but very few exceptions, vessels pass Tchernavoda, and go straight on to Ibraila or Sulina; for, in practice, it has been found either more economical or more convenient to take the longer water route. This is another example showing how, in certain cases, preference is given to a very circuitous waterway, instead of to a direct route by land.

On leaving Tchernavoda, the Danube bends to the north and continues that direction to Galatz (13 miles below Ibraila), whence it flows east by south to the sea.

The river between the Iron Gates and Ibraila has frequently a depth of over 40 feet at low water, but at seasons of very low water its bed is encumbered in several places by sand banks, on which the depth is not more than 9 feet, and at 3 shoals, Nicopoli, Sistov, and Tchernavoda, not far below the railway station, the depth is at extreme low water reduced to 7, 6, and 4½ feet respectively. Still the navigability of this long stretch of the Danube, which has never yet been "doctored" by an engineer, may be considered in a good condition compared with other European rivers of anything like the same importance.

Between the Iron Gates and Ibraila, the average width of the main Danube (for *en route* it splits into many branches, forming numerous islands) before it floods its natural banks, is about ½ mile. The extreme difference between high and low water varies from 24 feet 6 inches at Turn-Severin to 23 feet at Nicopoli, and 19 feet 6 inches at Ibraila.

DANUBE FROM IBRAILA TO THE SEA.

In obedience to the special request of my friend, the President, I shall now inflict upon you *a mauvais quart d'heure* in describing the nature and intention of some of the regulation works which have been carried out under my direction as engineer-in-chief in what may be called the maritime section of the Danube, since the conclusion of the Crimean War—at which epoch the river below Ibraila was in a state of nature, that is to say, unruly and entirely untrained.

From the port of Ibraila, at the head of the maritime section of the Danube, the navigable channel to the Sulina mouth (116 miles) is under the control of the European commission of the Danube. This Commission, by virtue of the Treaty of Paris of 1856, was charged to remove the sand banks which obstructed the navigation between Isaktcha at the head of the delta, and the Black Sea, and authorized to levy tolls on shipping to cover the expenses of the work. Its jurisdiction was extended to Galatz by the Treaty of Berlin of 1878, and further extended to Ibraila by the Conference of London of 1883.

As a "Description of the Delta of the Danube," of "Works executed at the Sulina Mouth," and of "Dredging in the Sulina Branch," have been published in the minutes of the Institution, I need only here describe, as concisely as I can, the nature and result of the works which have been undertaken and completed below Isaktcha since 1856 in the river itself.

At the creation of the Commission, the depth of the navigable channel between Ibraila and the bars of the Kilia and St. George was nowhere less than 17 feet and 15 feet respectively, and as the permanent establishment of 16 feet on the bar of whichever mouth of the Danube might be chosen ultimately for special treatment was all that was then considered necessary for the navigation, no provision was made in my first estimates for the deepening of the river channels between the head of the delta and the Kilia and St. George's mouths. In estimating the cost of improving the Sulina mouth, however, the removal of the numerous shoals in the Sulina branch was, of course taken into account; but before referring further to this subject, I desire to say a few words regarding the removal of an isolated shoal which cropped up unexpectedly several years after the provisional works at the Sulina mouth (which, for economical reasons was selected in 1858 for special treatment) had been successfully completed.

I should premise that in June, 1857, at a period of ordinary summer flood, when the water attains the level of the natural banks of the delta, I found by exact gaugings that the total discharge of the main river in the first reach above Ismail Chatal or Fork, 14 miles below Isaktcha, and 55 miles below Ibraila, was 325,000 cubic feet per second, of which

205,000 escaped by the Kilia branch.* I also ascertained that the minimum depth of the navigable channel in the Toultcha branch close to the Chatal was 19 feet at low water, and 30 feet at ordinary high water, over a width of about 400 feet. The existence of such an excellent waterway at the very threshold of the Toultcha branch was naturally regarded as very satisfactory, its navigable section being much superior to the normal sections lower down stream. In 1869, however, the depth of water at the same spot was found to be less than on a similar shoal which had always existed, and which will be referred to presently, at the entrance to the Sulina branch, 11 miles below Ismail Chatal. The appearance of a new and menacing obstruction at such a critical part of the river, gave rise to great anxiety, and dredging was at once resorted to as a means of giving the speediest relief to the navigation.

In spite of long-continued dredging operations, and of a temporary improvement by natural scour in the winter of 1871–72, the depth of the water at zero or lowest water over the new shoal in June, 1873, was reduced to 9 feet, or 3 feet less than in the worst part, at that time, of the Sulina branch. This serious diminution in depth at a vital point of the river called for immediate action of a drastic kind, and accordingly, before the end of the campaign of 1873, the main portion of the training works I had designed three years before were completed with great rapidity by Mr. Kühl, M. Inst. C. E., the able and energetic resident engineer of the Commission. From that time to the present the channel at Ismail Chatal has gone on steadily improving, and is now in a better condition than it has ever been before in the memory of man. The unique work that effected the cure—for the channel has never given any trouble since—is simply a curved dyke of rough rubble stone, 1,400 feet in length. This longitudinal training wall is connected with *terra firma* at the Chatal by a straight groyne, 600 feet in length, of the same height as the dyke itself.

The Sulina branch discharges 24,000 cubic feet per second at ordinary high water, or $\frac{2}{21}$ of the total volume of the Danube, when the river is 9 feet above the level of the sea at St. George's Chatal. At low water, or 1 foot above the sea at the same spot when the river in its course of 50 miles to the sea has a slope of only $\frac{1}{4}$ of an inch per mile, the discharge is reduced to 5,300 cubic feet per second. At extraordinary high water, when the inclination is 3 inches per mile, and the whole delta is submerged, the volume is increased to 70,600 cubic feet per second.

Although the volume of water discharged by the Sulina arm varies from 1 to 13, and the velocity of the current varies from $\frac{1}{2}$ mile to $4\frac{1}{2}$ miles an hour, the weight of sediment carried in suspension varies from a minimum of 12 grains to a maximum of 840 grains per cubic foot of water, or 1 to 70. The mean annual discharge of sediment by the Sulina is 5,000,000 tons, the proportion in weight to that of water giving an average of about $\frac{1}{3000}$.*

When the improvement of the Sulina branch was first decided upon, its course of 52 miles was impeded by eleven bends, each with a radius of less than 1,000 feet, besides numerous others of greater radius, and its bed was encumbered by ten shifting shoals varying from 8 to 13 feet in depth at low water. The width of the upper part of the branch varied from 500 to 800 feet, and that of the lower half from 600 to 750 feet. In the first case shallows existed wherever the width exceeded 500 feet, and in the second there was no appearance of a shoal where the width was limited to 600 feet. Consequently the first projects which aimed at securing a minimum depth throughout of 15 feet were designed to narrow the river to the width that nature herself seemed to indicate as sufficient to maintain the depth desired. Experience, however, has since shown the necessity of narrowing the channel to 400 feet in the upper section, and to 500 feet lower down, in order to maintain the depth obtained either by dredging or natural scour.

Owing to a want of funds the Commission was only in a position to proceed

* The flow past Isaktcha at extraordinary high floods, when the delta is submerged, is estimated at 1,000,000 cubic feet per second.

* The mean annual discharge of sediment of the whole river before it divides at Ismail Chatal, in the ten years ending 1871, was 67,760,000 tons, the maximum discharge (1871) being 154,000,000 tons, and the minimum (1866) 12,500,000 tons.

slowly with the river works, and many years elapsed before a clear gain of 4 feet in depth could be obtained throughout the branch. During that period of transition it was proved over and over again that dredging, although often resorted to to give temporary relief to the navigation, was altogether inadequate to ensure a permanent improvement, for, owing to the vast amount of detritus carried in suspension, as well as to the sand rolled along the bed of the stream, the shoals, which were still untouched or but partially treated, were invariably in process either of augmenting in volume and height during floods, or of deepening and diminishing in bulk as the water subsided. Occasionally a shoaling of from 2 to 3 feet would take place, when no particular reason for its formation could be assigned, and until the unexpected obstruction was removed by dredging much inconvenience was experienced by the navigation.

Time only allows me to give a very meagre description of the river works which have been constructed to regulate and fix the channel, and two examples must suffice as types of the methods which have been employed, as a rule, to attain the end in view.

The object of the first works was to confine the waters within certain limits where required, so that the floods might operate in deepening the channel sufficiently, but not so violently as to cause excessive scour, an effect which only gives an abnormal deepening, not needed at the expense of the river lower down where the depth is already insufficient for the navigation. As before remarked, this "*juste milieu*" of width was found in practice to be 400 feet in the upper half of the Sulina and 500 feet in the lower half, and these widths have accordingly been adopted. The worst shoals in the Sulina branch, before its correction was taken in hand, were found at St. George's Chatal and at Algany, 3 miles lower down. The latter being then the worse of the two was attacked first, and will be first described.

In its natural state the shoal extended from bank to bank. a width of 700 feet, and the depth over it at low water was only 8 feet. The first works consisted in the construction of several low groynes or spurs from the left or concave bank, and in the closing of a subsidiary stream. These preliminary works produced an appreciable improvement in the first instance, but as two years afterwards the shoal began to deteriorate, it was then decided to confine the river within artificial works 500 feet apart carried up to the full height of the banks. This was accomplished by the construction of a curved longitudinal dyke joined to the left shore by a straight groyne and by the projection of several other groynes and a small longitudinal work from the right bank. The channel was dredged at the same time, as, unlike most of the other shoals, the bottom consisted of hard clay which resisted the erosion of the current. Notwithstanding this treatment, a depth of from 13 to 14 feet could only be maintained by occasional dredging, and it was not until the channel had been narrowed to 400 feet that the existing depth of 15½ feet could be constantly maintained without further artificial aid. The groynes, as at all the other shoals, are composed of fascines of willows or reeds bound together with iron wire on frameworks of timber sunk *in situ* and revetted with stones from the bed of the stream up to the level of high water. The root ends of these spurs speedily become incorporated with the river banks, but their outer ends require careful maintenance to protect them from the attacks of ice in winter when the navigation of the Lower Danube is generally suspended for a period of two or three months.

In my first project for the correction of the Sulina branch, I recommended the opening of a new entrance from the Toultcha branch favorable in its direction for the navigation, and intended to supersede the old entrance at St. George's Chatal, which was difficult both of ingress and egress, owing to its exceedingly tortuous and shallow channel. This scheme lay on the shelf until the improved finances of the Commission enabled it under my advice to undertake the work in 1880, and to complete it in December, 1882. The state of the old Chatal underwent many vicissitudes, until it was finally abandoned. For want of money nothing but dredging could be done in the early years of the Commission to maintain the channel at the depth of 12 feet at zero or lowest water. In 1865, however, this constantly-recurring expense was found to be so unsatisfac-

tory, and the persistent erosion of the Chatal point by strong currents and floating ice became so alarming as to cause me to advise the Commission to lose no time in constructing protective and training works at the Chatal, and to exhaust every legitimate endeavor to improve it before resorting to the plan of cutting an entirely new entrance, which, at such a delicate point, would entail a certain amount of risk, and an outlay which could be better applied for the moment in the construction of still more urgent corrections down stream. My proposition being accepted, the first work was begun in 1865, and consisted of the revetment of the concave bank, and a continuation of the latter on the same curve, 600 feet, by means of what may be called a half-tide spur of rubble stone 350 feet long, terminating in the Toultcha branch at a depth of 16 feet at zero. The spur effectually stopped any further erosion at the Chatal point, but failed to give any additional depth, and it was not until the work was crowned with a palisade of timber brought up to the level of high floods, combined with the projection of a half-tide straight groyne from the opposite bank, thus narrowing the pass to 450 feet, that an appreciable deepening of the channel occurred. This improvement continued until 1870, when the descent of an extraordinary high flood threw down such a mass of deposit at the Chatal that the available depth was at once reduced to 8 feet at zero, thus diminishing the depth of the channel fully 4 feet in less than three weeks' time. This rapid shallowing, following a gradual improvement of five years' duration, seemed to prove that the width between the curved spur and the opposite bank was still too great at times of high flood to prevent injurious deposit at the Chatal channel, and therefore the straight groyne was at once raised to the level of the river bank. This additional work, together with dredging, soon restored the channel to its former condition, and the improvement continued until April, 1875, when the survey showed a fairly good channel of 15 feet at zero.

Shortly after that time, however, the depth again began to fluctuate between 11 and 14 feet, and these constant changes in the bed of the stream, added to the inherently vicious direction of the entrance itself, became at length so intolerable to the long steamers which now trade to the Black Sea ports, that urgent demands were made for the cutting of an entirely new entrance. This request, as we have seen, was complied with.

The new cut, ½ mile above the old Chatal, has a length of 3,300 feet, an average depth of 24 feet, and a bottom width of 300 feet, with slopes of 1½ to 1 and 1 to 1. It was begun in June, 1880, and its contents of 1,057,000 cubic yards of clay and sand were removed by the aid of dredgers, floating tubes, and hopper barges by December, 1882, when the new channel was opened to the navigation. In the four following months there was a silting up of 3 feet in the new channel, and of 4 feet in the old one, owing to the velocity of the current in both channels being considerably less than in the reach immediately below them, and it was not until the old branch was entirely closed by a solid dam that the *regime* of the lower part of the Sulina branch was restored. An accelerated current swept away the recent deposits in the new cutting in proportion as the dam in the old branch was raised to the water-level, and within two months of its completion the whole mass of sediment, 187,000 cubic yards, an accumulation of less than six months' duration, was swept away by natural scour. The new channel then assumed the normal area of the improved sections of the river, and, with but few modifications, has retained it to the present time.

The programme of the Commission for improving the navigation of the Lower Danube is on the eve of completion. Between the ports of Ibraila and Sulina there is now everywhere a navigable depth of from 17 to 20 feet at the season of high water, and a minimum depth of 14 feet at low water. In the Sulina branch nine of its worst shoals have been successfully dealt with, three cut-offs have been made, by which the river has been shortened 2 miles, eight of its worst bends have been entirely suppressed, and a length of 10 miles of stone revetment to protect the banks has been constructed. The total cost of those river works, including maintenance and dredging, has not exceeded £300,000.

At the Sulina mouth, where there was only a depth of from 8 to 10 feet before

the construction of the piers, the depth for many years past, unaided by dredging, has not been less that 20½ feet. The cost of the piers, including their maintenance to the present time, has been about £220,000.

The effect of these improvements has been to increase the trade from 680,000 gross tons in 1859 to 1,530,000 gross tons of 2,240 lbs. in 1883, and to lower the charges on shipping from an average of 20s. per ton for lighterage before the deepening of the Sulina mouth and the improvement of its branch to less than 2s. per register ton at the present time for commission dues.

Two-thirds of the trade are now carried by English steamers, which usually ascend to Galatz and Ibraila at ordinary high water to discharge merchandise or coals, and to load with grain. At seasons of low water they prefer, as a rule, taking in their cargoes at Sulina from iron lighters drawing from 8 to 12 feet, and carrying cargoes of from 300 to 1,000 tons. The average charge for conveying grain down stream by these lighters, which are towed by steam tugs from Ibraila to Sulina, exclusive of loading and discharging, is 0.20 of a penny per ton per mile, and 0.33 of a penny per ton per mile for the transport of coals from Sulina to ports up stream.

It may be encouraging to young engineers who have difficult river and sea undertakings on hand—in the ultimate success of which they themselves have implicit faith—to learn that the works I have just described are almost identical with my first projects in 1857, which were emphatically condemned in 1858 by an international commission of distinguished engineers—who had never visited the grounds, in the following terms: "The Commission cannot recommend the application of the proposed system of improvement, which offers no guarantee of success. As for the projects for the Sulina mouth and branch, they ought not to be carried out; their success is very uncertain, they will be of no real use; they will cause the total loss of very large sums of money, and will even throw obstacles in the way of existing navigation." And even in stronger terms than these they condemned my plan of provisional piers at Sulina, which in three years' time (1858–1861) increased the depth on the bar from 8½ feet to 17 feet, at an expense of only £86,000. These provisional works they reported in 1858, to their Governments, "should be immediately abandoned, if already commenced, for not only would they be useless for the purpose intended, but the guiding piers themselves would speedily be destroyed by the force of the waves, owing to their feeble section."*

As a commentary on the above, I need only draw attention to two facts—namely that the execution of the works so unsparingly criticised in 1857, has already effected a saving of upwards of £20,000,000 sterling, and that experience has abundantly proved that the predictions of a rapid silting up to seaward of the Sulina piers, which were so prevalent at one time, were happily unfounded; for, on the contrary, the entrance was never so free from sand banks as at this moment, as will be seen at a glance on referring to the last survey of the Sulina mouth in November, 1884.

I cannot quit this subject without calling to mind the eminent services of my steadfast old friend, Col. Sir John Stokes, K. C. B., R. E. (whom I am happy to see in front of me to-night), whose prompt and energetic action at moments of financial and other difficulties, which beset the European Commission of the Danube during the fifteen years from 1856 to 1871 that he acted as H. M.'s Commissioner, has contributed more than anything else to the complete success of the governing body, which for the last twenty-nine years has exercised almost sovereign power on the lower part of the river.

And now, I am happy to say, our bad quarter of an hour is at an end, and that it only remains for me to conclude my lecture by a few practical observations, which have suggested themselves to my mind, on reviewing the facts which I have ventured to bring under your notice this evening.

* As a substitute for the parallel pier system at the mouth itself, the Technical International Commission recommended the construction of a lateral canal 16 feet deep to the St. George's branch of the Danube from a point on the sea-board about ⅜ mile to the north of St. George's mouth, at an estimated cost of £360,000. If this plan had been executed, the cost of the canal up to this time, including maintenance, would have amounted to at least £600,000, and the navigation, instead of enjoying, as at present, a depth of 20½ feet at a wide, open mouth, would have been compelled to enter and leave the Danube through a narrow locked entrance of solid masonry, with only 16 feet of water over its sill.

It may have been remarked that I have taken some pains to ascertain the actual available depths for navigation in the principal inland waterways of Europe. This procedure has involved a considerable amount of correspondence with some of my colleagues at home and abroad, to whom I take this opportunity of tendering my grateful acknowledgments for the kind manner in which they have responded to my solicitations, for certain precise information, within their personal cognizance. The question of improved inland waterways is one that eminently deserves the attention of English engineers; but, unfortunately, since the establishment of the railway system in this country, the construction of canals and the improvement and canalization of rivers has ceased to be appreciable. Such, however, is not the case abroad. On the great inland navigations on the Continent the permanent acquisition of even a single foot of additional depth between great trading ports in the same or in an adjacent river basin, is considered of immense importance, and worthy of being attained at a great cost; and striking examples of this assertion, in France and in Germany, I have endeavored to lay before you. In no other way than by deepening existing channels and by acquiring new ones of comparatively great depth, can a wholesale and wholesome competition with railways for the transport of heavy goods be brought about. With regard to the permanent deepening of large rivers without the aid of locks, the question is a very difficult one, and, unfortunately for civil engineers, there is no golden rule to affect this grand desideratum; for every river must be studied *per se*, as it by no means follows that a system of improvement that has answered well at one spot will be equally successful at another. Where a large river has many shifting shoals throughout its course, it is comparatively an easy matter to get permanently rid of one, two, three, or even more of them; but the crucial difficulty, especially in rivers heavily charged with detritus, is to get rid of every one of the shallows down to a depth where water transport can successfully compete with railways.

If, for instance, only a single shoal remains, which demands transhipment at certain seasons of the year between two important seats of trade on the same river, that shoal, like the weakest link in a chain, which is the measure of its strength, will be the real standard of the value of the river as a navigable highway. Again, until rivers in different basins are radically dealt with so as to insure a sufficient navigable depth at all seasons, it is almost useless to join them by constructing canals deeper than the river channels they connect. Thus, for example, the Ludwig Canal joining the Danube and the Main can never be profitably worked until the navigable channel of those rivers has been very materially improved and the same remark applies to the proposed canal between Vienna and Oderburg, at the ends of which the Danube and Oder have but comparatively narrow navigable channels. It goes without saying, that intractable rivers can only be profitably dealt with by using them as feeders for lateral canals furnished with locks, or by canalizing the rivers themselves, with ample provision by means of movable dams or otherwise to enable the floods to pass freely without detriment to the navigation. In either case, apart from the question of depth, the locks should, wherever practicable, have dimensions approaching those now being constructed on the Lower Seine. It need not be added that another element required to enable a canal to prosper as a great carrying highway is a great increase in speed, an improvement which can only be accomplished by enlarging the sectional area of the canal, by the best known mode of traction, and by protecting the banks against pernicious erosion.

As I remarked at the beginning of my lecture, it has not been my intention to discuss the relative cost of rail and water conveyance. Railways will prosper where water communications languish, when the latter labor under great physical difficulties, as on the Rhone and the Ruhr, and where, as in the United Kingdom, canals are handicapped by frequent locks and insufficient sectional area.

On the other hand, waterways will flourish, as on the Seine, in Belgium, and in Southern Germany, where the winters are comparatively short, where tolls are merely nominal, where locks are large and infrequent, and where a good navigable depth is constantly maintained, so

that vessels of large tonnage—*the great desideratum* in economical water transport—can nearly always be profitably employed.

I have abstained advisedly from alluding in this discourse to the Corinth Canal, now in progress, or to certain well-known projects for overcoming isthmian difficulties of a like nature elsewhere, either by means of artificial water channels or by ship railways. It is one of the traditions, I believe, of this Institution, to discourage anything like a serious discussion, within these walls, of public works that are still in embryo, or under construction, and of course I shall not attempt to infringe this salutary unwritten law. I may remark, however, with regard to such great enterprises, that whatever may be their ultimate fate, the number of great isthmian schemes must necessarily be very limited, and, that in this respect they differ materially from ship canals of an inland, and therefore of a less ambitious character. Whatever, for instance, may be the result of the Liverpool and Manchester scheme, now before Parliament, it is evident, I think, that a grand future is open to works of that class; and I venture to predict that the improvement of water communications between the sea and inland towns of importance, by means of canals or of deep, open channels planned so as to *aid nature* in maintaining permanently their increased depth, will continue to go on briskly after the last ghost of a practicable inter-oceanic waterway has been finally laid.

SOME THOUGHTS ON ARCHITECTURAL TRAINING.

A Paper read before the Architectural Association by W. J. N. MILLARD.

From "The Building News."

In offering you a few stray thoughts on architectural training, a question which has for a long while interested me, I certainly cannot claim originality as to the subject chosen, nor perhaps for many of the ideas I have attempted to string together; but I trust you will allow the apparent staleness of my subject to be outweighed by its importance to us and its peculiar fitness for discussion by such a body as our Association. Since, moreover, it seems to be a question on which the last word has not yet been spoken, by any means, we may possibly still find one or two points worth considering, or even reconsidering, in spite of everything that has been said and written concerning it. In fact, regarding some points, one is half tempted to ask, "What has all the attention given to the matter of late years really amounted to, so far?" To say nothing of the destined victims themselves—the pupils-to-be—standing, so to speak, on the brink of the profession, about to take their great "leap in the dark,"—are the parents and guardians, up to the present time, any better informed, or enabled to inform themselves much more clearly than hitherto, about what is involved in an architect's training and subsequent career? What are the main requirements and the chief conditions essential to success, or, at least, to avoidance of failure, in such an undertaking? Here, to begin with, lies the possible source of much mischief which might be rendered more preventible than it is by us architects. The immense importance of any reliable information that can be obtained with regard to an architectural career, before committing a youth to it for life, must be obvious; and surely it rests with us, and us alone, to enlighten the outside public in this respect. As yet, however, I fail to see where the parent is to turn with certainty of obtaining anything more than the most meagre hints to help him to a decision in such a case; and still, it seems to me, it ought to be quite possible to afford him ample means of fully weighing a step so grave in its consequences for his *protege* before letting him take it. For instance, a students' manual or textbook might be drawn up, one would think, and issued under the joint sanction

of the Institute and the Association; embracing the entire training of an architect, and setting forth in detail all the various branches of study, with the order in which they could be best taken up according to circumstances, as well as other items of information bearing on the subject. To accomplish this much effectually, would perhaps call for a little more unanimity than seems to have prevailed until now, as to the main lines to be laid down for an architect's training; but I hope we may really take it that all the interest recently exhibited about the whole question is evidence, at least, of a genuine desire for some more general agreement. The project of a student's textbook to be published by the Institute, was put forward in a paper by Mr. Phené Spiers, as long ago as the general conference of 1871; but, for some reason or other, it seems to have fallen flat. May-be vested interests in the pupil-farming system were too powerful in those early days for any so radical an attempt at reform. It is true, the A. A. "Brown Book," and the lately-issued "Kalendar" do give particulars of many things a student may want to know, such as our classes and the examination, thus fulfilling their purpose well enough, each in its way. The "Kalendar" is now to include the questions set at the previous examination; but we seem to be in need of something far more comprehensive in its aims—a production that should if possible be the outcome of the united counsels of all those best qualified to advise, and so be rendered valuable as a guide to parent, principal, and pupil alike. Since the feelings and opinions current amongst juniors of the profession would have to be taken particularly into account in preparing any such work, we could not be doing amiss this evening to quietly discuss a few matters of which it might treat. With this object I proceed to throw out a suggestion or two for your consideration. To begin with, then, it would not be inappropriate, by way of an introduction, to call to mind what is usually comprised in an architect's practice—to which his training is professedly a preparation, and to afford some conception of the wide range of subjects he is expected to deal with. How, for instance, he is of course supposed capable of designing almost anything, from a Christmas card to a cathedral; and is liable at any moment to be appealed to as an authority on nearly all conceivable matters, from a leaking gaspipe to a question of church ritual arrangement; or, again, to be called away from playing the part of a building detective to decide upon a doubtful point of archæology, not to mention other things innumerable, showing clearly that, although architecture is the work of architects, the converse will scarcely hold good invariably. It might be interesting and instructive, in the next place, to follow this up with the means commonly taken to equip the aspiring youth for an enterprise of such magnitude, giving a brief unvarnished recital of the time-honored course of procedure so familiar, I will not say endeared, to most of us; recounting how the raw pupil gets pitch-forked, all unprepared as he is, into an office, the busier the better; and, how, only too frequently, his wasted years of innocence are terminated by rude awakening to what he ought to have been learning all the time on finding himself, at the expiration of his articles, helpless. This to anybody of an inquiring turn of mind, must bring home the question, supposing it has never occurred to him before, whether no improvement is possible, whether no saving of valuable time can be effected in a pupil's usual course of training; and, if it can, how? Even so much as to put him into the way of teaching himself, to show him how to use his eyes and pick up what he can on his own account, is not unfrequently to do him quite a good turn, as elementary instruction for architects goes nowadays. Hitherto, a lurking sort of idea seems to have possessed parents, architects and pupils alike, that for about the first year, at any rate, it cannot really matter so very much how a pupil is employed, and, as I have known it to be said by an architect, too, that "a year or so of office drudgery will do him good!" Will it? May we feel quite certain it will do no harm? Why, herein, possibly, lies a clue to the mystery of that spectral apparition we so often see, calculated to touch the conscience of architects (if anything will)—I mean the time-expired pupil, wandering round disconsolate in search of his first berth as an assistant; whilst his good friends and relations are grow-

ing every day more and more concerned about him, marveling how it is he does not manage to "do something." Poor fellow! Alas, generally speaking, it is so precious little he can do. He tells you naïvely how he would so like to get with some "good man," where he would "learn something." That alone speaks volumes. He finds, in fact, he has just come to a most critical turn in his course. For a last resource, perhaps he goes, out of sheer desperation, as an "improver," in hopes of learning something. Save in certain exceptional cases, I can seldom hear of an instance of that nondescript, the "improver," without suspecting there must be something wrong somewhere, and, not improbably, as much of misfortune as fault on his side. Altogether, is it not enough to suggest a doubt, whether the ordinary architect's office is invariably the best possible place for a boy fresh from school; and whether the practising architect, be he prosperous or struggling, is precisely the man to undertake the responsibility of such a charge? Almost any head draughtsman can tell you how young pupils are usually regarded as a nuisance in an office, secretly or openly, until they have proved themselves to the contrary; but how they must, of course, be tolerated for the sake of their premiums and the dim hope of their making themselves useful some day before the term of articles is "up;" and how it is time enough to trouble much about them when (if ever before then) they become, somehow or other, sufficiently advanced to be trusted with office work of any consequence. To slightly vary the well-worn metaphor—"as the boy is to the man, so is the pupil to the architect." We do not find the question of "bringing-up" lightly regarded by the majority of thoughtful parents in respect of their children, not, at least, so long as they are still too young to take to architecture as a profession. And seeing that, in other branches of education, the art of teaching is generally held to require some sort of special training, and even special gifts, for it to be followed with success, the wonder is how intelligent men of the world, who have to decide on a career for their sons, can go on supposing that corresponding conditions may be dispensed with in an architectural education. But, as yet, how are they to be aware whether or not they ever incur any risk at all of such conditions being unfulfilled, unless, indeed, the architects they treat with should themselves say as much, a course of procedure only conceivable on the assumption, in the first place, that even they are firmly persuaded to that effect. Happily, at last there does appear a tendency, actually amongst architects, towards agreement to this much, at any rate, viz., that a regular course of distinctly preparatory training is almost essential for a pupil before being launched straight into an office if he is to derive full benefit from what he sees going on there. This point, finally accepted, would involve the further one, as to what should be the nature of such preparatory work; in short, how best to begin an architect's training. Or is this ever to remain a case for "toss up?" By no means the least part of the difficulty in deciding on any course arises from the very variety of studies the pupil might begin with, coming under the four main heads of Art, Science, Literature, and Practice. One thing, at any rate, is pretty certain—he cannot plunge indiscriminately into them all just at first. No sensible man, with a dozen important affairs to attend to, will attempt to take them together in a lump, but will at once set about arranging them in some suitable order. No beginner at architecture can be reasonably expected to acquire a dozen branches of professional knowledge all at the same time; he needs careful guidance—nowadays more than ever—as to the best order in which to proceed; even supposing the economizing of time be his sole object. Then another difficulty meets us in the fact that the same course may not be equally well suited to varying capabilities. Yet, surely, it ought to be possible to indicate a path which no one could be any the worse for pursuing, a certain distance at least, to begin with—that is, if he is ever to be an architect at all. Doubtless, we shall hear plenty of excellent and powerful arguments in favor of a preliminary course of technical education or applied science rather than purely artistic training. I venture, with all respect, to put in a plea for the latter being made much more than it is, the basis and backbone, as it were, of an architect's education and whole career, the very foundation to build up

from. I should like to see an architect commence oftener with a sound artistic training, including geometry and perspective, side by side in a school or studio with other art students. It is rank heresy, of course, to breathe the shadow of a doubt as to the immense advantages of a so-called practical training; but it may be at least permissible to discuss whether this is always the best way of beginning, and whether a thorough knowledge of what comes under the head of practical work might not be acquired by a student just as well, or even better, than in shorter time after he had advanced somewhat and there was a likelihood of his receiving the bearing of such studies and of then realizing the unquestionable necessity for his mastering them as one main condition of ever being able to practice his profession. No more potent influence was ever invoked in aid of successful teaching of any sort than the infection of the pupil himself with a desire to learn. This, if possible at all, is most likely to be brought about with work he most cares for at the time. If, therefore, an architectural beginner's own inclinations lean, ever so slightly, towards art rather than science, would it not be a trifle unwise to disregard them and to court failure, by putting him through the "mill" of a scientific or practical training from the first—beginning, as it might prove at the wrong end? The consideration of what he himself may want to be taught will be hardly worth neglecting entirely for the sake of compliance with some supposed infallible programme of cut-and-dried correctness. Rather let the loose rein, given in the first place to his natural tendencies, be used as a means to lead him little by little. All in good time, no doubt, he will want to know about practical matters, and will be far more disposed to devote himself to the intelligent pursuits of them—in view of their absolute indispensability to him as a practising architect—when he is old enough to feel clearly convinced of this fact. And it is a fact, the full importance of which he will never be made to feel by mere reiteration. Again, even in the case of those who may not, so far, have given unmistakable indications of genius, or whose natural bent still rests undefined; just average young beginners, say, with all their inherent imperfections, carelessness, ignorance, laziness, or stupidity; a preliminary trial of artistic instruction is still as likely as anything else to enlist their better qualities, and has at least the recommendation of leaving no unpleasant distaste or harmful results—supposing it should, after all, fail to disclose latent talent. Nor need it be lost time, since every architect, to be worthy of the name, must at some period or other attain to a certain amount of proficiency in freehand drawing—as distinguished from mechanical—and the earlier he does this of so much the more service will it be to him. It is something he can apply in his everyday work, and thus, at the same time, ensure from becoming rusty and useless, as may easily happen with some kinds of knowledge if acquired sooner than need be. How an architect can gain command of his pencil too soon is difficult to make out. But beyond all this, is it not also worth our while to consider, for a moment, the positive harm that may be done to any youth blessed with so much as a single spark of artistic fire, by deferring the careful and systematic development of such a gift until after he has been wearied and nauseated with what may well appear to him at first as the less attractive and less stimulating side of his profession? If there be one thing more than another that needs, and at the same time repays, skilful tending, from boyhood upwards, it is surely this lamp of art; whereas, on the other hand, its flame is by no means to be kindled at will, just any moment a man may decide to "go in for the artistic." The comparative rarity of a wild plant may sometimes be apparent only, rather than real, owing to its general unobtrusiveness: but granted, that, in this case, the shoot might be but a feeble one—the smaller the growth, the greater the need, perhaps, to prevent its being blighted and hidden for ever; and the season for bringing it forward to good purpose, once let pass, may never recur. In such an instance, it would seem, anyhow, to be running a smaller risk to postpone awhile the taking-up of some other branches of study. Every now and then, in looking at executed designs, one cannot help feeling that the authors might easily have been made so very much more of as artists, by other training; to judge from the evidences of considerable artis-

tic power—somehow strangely undeveloped—marking their work, which differs, at the same time, distinctl from that of the simply feeble designer, destitute of any ideas of his own, and only just sufficiently clever to ape the art of better men. Ask many a worthy practitioner whether, in his heart of hearts, he does not deplore his lack of early artistic encouragement and guidance, and feel that this might have made all the difference. To save even a single student from the fate of turning out, in an artistic sense, a dwarf or a cripple for life—if it can be prevented—appears well worth the attempt. To catch hold of him and turn his brighter side to the light; to draw out his finer feelings whilst yet unblunted; to arouse in him a healthy enthusiasm through the sympathy of his fellow-workers in a congenial pursuit, just at an age when he is most impressionable, may be doing a truer kindness than to ply him with all the most admirable instruction in the world, before he can half appreciate the good of it. As I believe in a good art school for the beginning, so I know of nothing equal to a good office for the finishing of an architect's training—outdoor study and travel coming in very largely between whiles. I will just allude to a proposal I made here, on a former occasion, for obtaining the privilege of a seat in a good office, by way of a "finishing," for such as should distinguish themselves in preliminary study. Might not the Architectural Association set an example of founding scholarships entitling the holders to serve for a period a sort of advanced pupilage in one or another of the leading offices, where they would have the advantage of doing good work along with other picked men? Any number of poor students would regard such a prize as indeed something to aim at; and further, we should be thus helping, in a way, to bring on a more accomplished race of architects. For whatever is gained from any course of instruction depends not only on whom it is the pupil works under, but quite as much on those he has to work with: figuratively speaking, they constitute the very atmosphere he breathes. Indeed, oftentimes in after-life, on looking back to such days, a man may be able to trace some decided change of direction in his career to the fact of his having then chanced to come in contact with certain other minds of different calibre from his own. A paper on "Architectural Training," however limited in scope, would be incomplete without some reference also to the examination. Now, the architect's calling may be said to combine the pursuit of an art with the practice of a profession. No man may lawfully set up as an attorney, a doctor, or even a druggist without first satisfying an examination test. Anybody may dub himself "architect" who chooses to, but so can anybody proclaim himself a painter, a sculptor, or a musician, without, however, any other folks taking it very seriously to heart. In these cases an abuse of title corrects itself in the long run. May not a like result be looked for in architecture, if only the standard in it of artistic attainment be more and more raised? But yet, on the other hand, how is it that people do not, as a rule seem to put such implicit faith in their architect as they will, for example, in their legal or medical adviser? Is it not mainly because these latter can invariably offer a sound guarantee to begin with of proficiency in their work up to a certain point? If, then, this be the true reason, it must manifestly tell to the architect's advantage also, as well as to his client's satisfaction, to have a similar assurance to give, as far as any examination test can be fairly applied and without prejudice to his position as an artist, still leaving that point to be determined in the same way as in the sister arts. I make no apology for assuming all along the possession of artistic ability to constitute one of the truest claims to the title of "architect." To some, of course, it may seem but a small matter for regret if by clumsy nursing we do manage to "choke off" or maim so many "budding artists" a year, leaving only the hardier survivors to flourish in spite of it; but do not let us forget that in the training of our pupils lies the key to the future of British architecture; and even for the present one does not hear many serious complaints of our poor profession being actually glutted with artists, whatever other forms of depression it may be laboring under. It is to be hoped there may ever continue to be pupils who, by force of talent, with or without good training, will in due time win credit to themselves and their profession; but we are dealing

with a matter affecting not a small minority only of exceptionally clever men, but that vast majority of average mortals like ourselves, who, whether or no, are some day to adorn or disfigure with their works our streets and suburbs and fair country-sides. Much might be said about a student's more advanced work and his preparation for practice. Important and interesting as these questions would be found, they must sink into insignificance beside the great initial one of how the training of an architect should be *commenced;* since in this, as in many another undertaking, it is the first move—the easiest one to make—which may influence so incalculably all that follows. And together with this point goes the one—at the root of the whole matter—whether some means or other cannot be devised for putting things a little more clearly and fairly before parents and guardians. In pursuance of my endeavor throughout to regard this subject in as broad a light as possible, rather than in detail, I will conclude with a proposition that may now appear to many self-evident, but, nevertheless, one, if true, whose more universal and loyal acceptance by architects in days past might perhaps, among other results, have rendered needless, not only this evening's discussion, but the very existence of the Architectural Association itself—viz., that our whole profession, as a body, is responsible for the training of its pupils.

STEEL SHIPS.

From "The Engineer."

It is now just ten years since the steel manufacturers of this country succeeded in producing a material suitable for the purposes of the shipbuilder and marine engineer. Previous to that time many attempts had been made, both in Royal and private shipyards, to employ steel in the construction of ships; but the results were not so generally satisfactory as to encourage further developments in that direction. The steel then being made was variable in its qualities, so much so that angle bars, which were very ductile at one extremity would sometimes be exceedingly brittle at the other. The behavior of the material was, indeed, very erratic and unsatisfactory. Some plates and bars would show the best qualities of tenacity and ductility, while others from the same batch would evince the possession of the several characteristics of hard tool steel. After much labor had been expended upon a steel plate, and when it was riveted in place, it would suddenly become fractured without any warning, and from no assignable cause, except, perhaps, change of temperature. The Admiralty were the principal users of steel in shipbuilding at that time; but the employment was limited to deck flats, stringers, and longitudinals, with the view chiefly to effecting economy of weights. Under no circumstances was it considered safe to use steel for the outside plating of her Majesty's ships. The French Government were more enterprising in this particular, and in 1874 it was found that, notwithstanding the treachery and imperfections of the steel supplied to their dockyards, they were able, by carefully observing certain precautions, to work that material into their ships upon a larger scale than our own naval constructors felt justified in attempting. The keystone of the difficulty was to be found in this very question of care in manipulation. It was not doubted that the behavior of the steel was governed by certain laws, and that a careful observance of those laws would be followed by success, so far as the manipulation of the material was concerned. But then, dockyard workmen are not skilled metallurgists, and to build ships with a material that required such careful handling was not only commercially impossible, but also impracticable, even at a Royal dockyard. Moreover, there was always the risk that by improper treatment the steel might be put into such a condition of initial strain by reason of changes in its molecular arrangement, as to cause a disaster to occur at sea to a vessel by a

rupture occurring at a place where undue internal strain would be wholly unsuspected. For these reasons, then, our shipbuilders had no confidence in steel, although they had every desire to employ a more tenacious and ductile material than wrought iron if it could be produced at a moderate cost.

It was in 1875 that Sir N. Barnaby, then Director of Naval Construction at the Admiralty, uttered his famous challenge to the steel makers of Great Britain in the the hall of the Society of Arts —at the annual session of the institution of Naval Architects. That challenge was taken up at once, and in the following year Mr. James Riley, the manager of the Landore-Siemens Steel Works, appeared before the members of the same institution with a statement showing what had been done by the company he represented towards meeting the requirements indicated by Sir N. Barnaby. The Director of Naval Construction had said in the previous year—"The uncertainties and treacheries of Bessemer steel, in the form of ship and boiler plates, are such that it requires all the care which it has had bestowed upon it at L'Orient to avoid failure;" and had further declared that we wanted "a perfectly coherent and definitely carburized bloom, or ingot, of which the rolls have only to alter the form in order to make plates with qualities as regular and precise as those of copper and gun-metal, and we look to the manufacturers for it." Said he. "I am ready, for my part, to go further than the French architects have gone, and build the entire vessel, bottom plates and all, of steel; but I know that at present the undertaking will involve an immense amount of anxiety and care." By the spring of 1876 the Landore-Siemens Company had satisfied Mr. Barnaby and the Admiralty so far that they were then fulfilling a contract for the manufacture of steel for the entire hulls of the two armed despatch vessels Iris and Mercury, which were ordered to be built at Pembroke Dockyard. Lloyd's Register at once gave attention to the matter, caused a vast number of experimental tests to be made upon the new steel, and so satisfied were the committee with its behavior that they proceeded without any delay to formulate rules for the construction of steel ships to be classed in their Register. The quality of steel described by Mr. Riley in 1876 is now being produced all over the country, and is known under the designation of "mild steel." Not only the Siemens-Martin, but also the Bessemer process is employed in its production, and attempts have been made to produce equally trustworthy steel by the comparatively new basic process, which, although not quite successful hitherto, will doubtless attain satisfactory results ere long. During ten years the cost of manufacture has been so reduced that the best shipbuilding steel can now be purchased at a lower price than was then paid for ordinary wrought iron. The employment of steel has correspondingly increased with the reduction in its cost, so that at present no less than forty per cent. of the tonnage building in this country is constructed of a material which ten years ago had no commercial existence, and was, indeed, scarcely discovered.

The present seems, therefore, a fitting time to review the developments which have been made in steel shipbuilding, and to consider the experience which has been obtained with the use of steel in the shipyard, and with the behavior of steel under the many tests to which they have been subjected. Hence it was not surprising to find three papers read upon the subject on the first day's meeting of the recent session of the Institution of Naval Architects, and a brief reference to these papers has already been made in the columns of this journal. It is to be regretted that so much of the subject matter of two of the communications referred to related to a personal question with which the Institution had nothing to do. Some of the points brought under the attention of the members by Mr. Martell and Mr. Ward are, however, of the deepest importance to shipowners, shipbuilders and underwriters. These relate to the old question alluded to by Sir N. Barnaby more than ten years ago, when he made his appeal to the steel manufacturers for a trustworthy material. Mr. Martell considers that it is still necessary to impose certain restrictions and regulations upon the use of steel such as he does not deem necessary in regard to wrought iron, and he produces excellent reasons for his opinions. Mr. Ward, on the contrary, has

reached such familiarity in the use of steel that he has become contemptuous with regard to its alleged infirmities and peculiarities. He would, therefore, treat steel in the same way as iron, neither better nor worse—that is to say, he would permit the workmen to heat, hammer and roll it to any extent they may please in fashioning it into shape, setting aside as bad only such pieces as fail under treatment. This is the invariable practice in shaping iron plates and bars, it being assumed that what is not cracked or broken is therefore sound, and fit to go into a ship.

Now, this is admittedly a safe practice in dealing with iron, but it is not everybody who considers it prudent to handle steel in such a way. The instance cited by Mr. Martell of the fracture at sea of a ship's plates which had previously been exposed to undue heat through a fire near the loading berth of the vessel, shows that in one case, at least, mild steel did not behave as ordinary wrought iron would under similar circumstances. On the other hand, as is well known to all familiar with the usual processes of a shipbuilding yard, it is a notorious fact that portions of a plate or bar are frequently heated and hammered without any injurious results following from that treatment. Indeed, if this could not be done, it would be unsafe to build steel ships without at least three times the amount of supervision which is now given to them by surveyors and inspectors. It is, in fact, doubtful whether any supervision at all would be effectual in preventing undue internal stresses from being set up in the molecular structure of the material of which a ship is built, if it cannot be safely handled by ordinary shipyard workmen. The importance of annealing thick butt straps in which the rivet holes are closely spaced, and of riming the punched rivet holes in thick plates of the bottom, may be admitted, without, at the same time, accepting such limitations as would practically exclude steel from mercantile shipbuilding altogether. Generally speaking, whatever wrought iron is capable of withstanding, can be much better withstood by mild steel, and this fact is made apparent by a comparison between the tests to which the two materials are subjected in order to determine their fitness for shipbuilding. The experience of ten years has shown that mild steel will usually endure very bad treatment without being seriously injured in regard to its ductility and tenacity. Instances are very rare in which the bottom plates of a steel ship have been penetrated by taking the ground, and it is not at all unusual for the bent plates to be taken off, rolled fair, and re-riveted in place. Whether such treatment is judicious is quite another matter, and it is very doubtful whether a vessel repaired in such a way is in so good a condition as she was before she sustained the damage in question. From the point of view of a shipowner whose ship is insured, the mode of repairing her to which allusion has been made seems very objectionable; and, indeed, under any circumstances there cannot be that close agreement between the rivet-holes of adjacent plates which is essential to sound work when a stretched plate is rolled fair and replaced in that way. Consequently, while we may admit the possibility of replacing bent plates after being faired by rolling, the advisability of so doing will not be so readily conceded. It is, of course, very satisfactory to find that steel is capable of resisting blows which would penetrate iron, and that in itself should be a sufficient return for the slightly greater cost of the former material, without our wishing to use stretched and over-strained plates simply because they appear to be sound.

Something can therefore be said from both the points of view of the cautious user of steel and from that of the man who would treat steel and iron in the same way. The former must remember that it is the excellence of steel which has made it so popular and inspired shipbuilders with such confidence in its qualities that it is now commonly employed for the most considerably bent, twisted, and furnaced plates in an iron ship's bottom. The latter should bear in mind that the very excellence of the material may often cause defects in its structure to be hidden, which would be revealed by an inferior article; for it by no means follows because a steel plate or bar shows no signs of cracking that it is not overstrained, and therefore impaired in strength. Damage to iron is at once revealed by fracture, but damage

to steel is often known only by a consideration of the treatment to which it has been subjected. While, therefore, steel is, in one sense, far superior to iron as a material for ships, it must yet be treated with more discrimination than iron, simply because it does not so readily disclose impaired conditions of ductility and tenacity. Nine hundred and ninety-nine out of a thousand of the operations in a shipyard are not calculated to do any violence to the structure of steel, if that of punching be omitted, but the thousandth establishes the necessity for taking care. The loss of strength resulting from punching is regularly restored by annealing or riming, and for the rest care must still be taken.

The corrosion difficulty has been overcome by carefully removing the mill scale previous to painting. As soon as this scale is got rid of, the risk of pitting and throwing off paint is at an end. Steel ships, which a few years ago were a source of much concern to their owners in consequences of rapid corrosion, are now no longer worse in that respect than their iron neighbors. Most shipowners take measures to free steel ships of the black oxide scale before they are launched, this being easily accomplished by the occasional application of diluted sal ammoniac or hydro-chloric acid.

The idea that steel ships will prove expensive to underwriters seems to be most fallacious. It is quite true that such vessels permanently alter their form when under stresses which would break an iron ship asunder. Several such cases have already occurred, and the impossibility of restoring those vessels to the same condition as they were in before being damaged has made them constructive total losses. But then the underwriter has held the damaged ship as a set-off to this claim of the shipowner for a new one, and although it has been impossible to make her perfectly fair and symmetrical, she has yet been repairable and made fit for service at a comparatively small cost. Both for the security of life and property, a steel ship is to be preferred to an iron one, and for that reason the rapid increase in the proportion of steel ships built every year is to be welcomed. But to maintain the superiority of steel ships, it is essential that every care should still be taken in the manufacture and testing of steel, and that familiarity with the use of the material should not result in the neglect of those precautions which experience shows to be still necessary in its manipulation, and which are not necessary when we are dealing with iron.

EARTH CONDUCTION.

By A. J. S. ADAMS.

From "The Electrician."

The future prospects of telephony and practical telegraphy would seem to be somewhat in the dark; but it is nevertheless unwise to discount the possibilities of such systems until we are possessed of a more exhaustive knowledge of the physical forces that are brought into play. Each successive step in elimination and elucidation is found to advance the general subject; and remembering how little is really known regarding some phenomena connected with electricity and magnetism, the surprise is that so much has been accomplished, and that there exists to-day such solid ground for congratulation and encouragement.

Our want of knowledge in respect to the telephone may be instanced by the several theories that have been advanced to explain the precise action of the telephone, and the remaining fact that no theory has yet proved to be incontrovertible, or to greatly modify our earlier conceptions. In respect to line conduction, our imperfect knowledge has been rendered conspicuous by the recent labors of Prof. Hughes, and by the experiments of Mr. W. H. Preece, and there is in connection with this point much yet to be learned. It is possible, however, to go farther, and show that our need of information obtains not only in respect to the

apparatus and to the line, but also in relation to the earth—where the earth's crust forms part of the circuit—and that the earth then exerts no inconsiderable effect upon the general result. In connection with this point it will be admitted that a telephone circuit, of which the earth forms a part, is never so satisfactory as it is where the circuit is wholly metallic, a feature clearly indicated in the interesting paper lately contributed to the Society of Telegraph-Engineers and Electricians by Mr. Preece, although it must be confessed the difference remains unexplained. Again, as regards the question of earth conduction, it may be remembered that in 1875 Mr. James Graves, of Valentia, contributed to the society already referred to an important communication upon "variations due to earth-plates," and detailed the extraordinary difficulties that were experienced by him in reading from the mirrors attached to the Atlantic cables, by reason of variations and disturbances which produced a constantly irregular motion of the "spot."

A brief consideration of this phenomenon may not be out of place at the present time, and possibly it may be gathered from the results of some experiments that have been made that the disturbance complained of by Mr. Graves possesses a marked and distinctive character, and, first, as to the probable resistance introduced into a circuit by the earth's crust. The earth cannot be considered as a conductor of electricity, apart from the moisture held by it; it is evident, indeed, that the earth's capacity for conduction will be to a large extent proportional to the moisture so held. When, however, the wide expanse of moist earth that almost necessarily divides two earth-plates is considered, it is difficult to apprehend any appreciable resistance to exist between them; and yet that some resistance is offered by the earth will appear from the following experiments:—Two clean copper plates, about 18 in. square, were buried 20 ft. apart to a depth of 4 ft. in a soil of loam, overlying sandy gravel. The earth plate electrolysis current steadily fell from first maximum to a point at which it was very weak, and then remained constant. Across and midway between the two plates shallow trenches were dug, and were kept supplied with water for some hours, the ultimate result being that, by reason apparently of the diffusion of moisture and the reduction of resistance, the current force increased several degrees.

The apparatus used was a sensitive Thomson reflecting galvanometer of 700 ohms resistance, and the scale was twenty-seven feet distance from the galvanometer, so that a very slight variation of force in the galvanometer would be well represented by the movements of the "spot." In the further experiment two flat coils of No. 18 copper wire were buried upright about 18 in. below the surface, and 4 ft. apart. The electrolysis current at first equalled a deflection of 38 in. upon the scale, but after falling steadily came to a stand at 18 in. from zero, and remained constant. The ground over and around these upright coils was now thoroughly soaked with water, and two days were allowed for diffusion. A trench was then dug of the same dimensions either way as the coils, between and parallel to them; the trench was a foot wide at top and tapered at the bottom. The effect of this trench was to decrease the deflection by 8 in. A small piece of dry board was ledged across the trench at its centre, and a child was instructed to build a bridge or road of damp earth from side to side over the board. The instant contact was made by the damp earth across the board, the deflection went up with a bound, and every succeeding reduction of resistance by the addition of earth to the bridge was clearly visible in the movement of the "spot." By this bridge the deflection was permanently increased by three inches, but again fell off as the earthen bridge dried under the sun. The effect of filling in the trench was also rendered clearly apparent by the swinging of the "spot" and ultimate increase.

It would thus seem that the earth's crust presents a higher resistance to the passage of electricity than would at first sight appear; secondly, and perhaps of greater moment, as to the apparent variability of the earth's conduction. Reference has been made to difficulties experienced at Valentia in reading the mirror signals received from America, by reason of irregular variations of the "spot," and which seemed to emanate from the earth plate. In that instance the disturbances could not be eliminated

until *earth* was virtually made by means of the sheathing of the Atlantic cables, instead of by the ordinary earth plate method. It may be stated that precisely similar variations are to be observed upon any circuit of which the earth's crust forms a part, provided that the means of observation are sufficiently sensitive, and that the wire tested is free from the larger effects of leakage, induction, and earth current.

Perhaps the most natural explanation that suggests itself concerning these variations is that of earth-plate variation —*i. e.*, a variation of the actual force generated at the plates, or of their resistance. In order to investigate the phenomenon from that point of view, the sensitive Thomson reflecting galvanometer was brought into use, and tests were made of a great number of combinations— simple and involved, new cells and old, pairs of similar and dissimilar metals —without once obtaining the slightest sign of the variation in question. In every case there was the usual electrolysis current, which steadily fell from a first deflection to a stationary minimum, and which by disconnecting the circuit, or by inserting heavy resistance, would temporarily increase; but nothing beyond that was noticeable. It was thought that in the case of an earth plate the deposited hydrogen might by some means be disturbed, and so vary the resultant force. To test this point the following experiment was made:—The ends of two clean copper wires were immersed in a jar of sand and water; in the centre of this cell was inserted a 1¼ in. glass tube, 3 ft. high, so that by keeping the tube filled with water there would be a circulation of the liquid up through the sand and around the wires, the idea being to effect a disturbance of hydrogen. No visible effect was produced, however, and it seemed clear the variation in point was not of simple earth-plate causation.

Another possible explanation of these variations suggested itself, namely, that the influence of slight earth currents upon the earth plates might produce an intermittent and changing state of polarisation. In order to investigate this point a No. 18 copper wire was erected and perfectly insulated, and extended from my house to a distance of 300 yards upon one side, and of 170 yards upon the other. The distant ends were terminated by means of large coils of the same wire, buried to a depth of about 6 ft. In my own garden similar *earths* were put in for use as might be required. With the Thomson reflecting galvanometer in circuit, whether upon the whole length of line, or upon the right or left sections, it was always necessary to shunt down the electrolysis current in order to bring the "spot" within the ten foot scale, and notwithstanding this reduction of current passing through the galvanometer coils, the variations under consideration were always present. This variation, this *constant* movement of the spot, was usually much greater in amplitude upon the 300 yards length than upon the 170 yards section. Why it was difficult to trace, but it may be added that a baker's oven, which was heated each day, lay directly in the line of the two *earths* of that section. Then, also, the amplitude of the variation altered very considerably one day with another, sometimes the swing of the "spot" being so much as eight feet from side to side, *i. e.*, four feet each side the zero. It was difficult to decide how the question of earth current causation should be attacked; the first experiment, however, afforded no trace of concurrency in the variations of the two sections of wire.

A further experiment was conducted with a view to question the effect of earth-current *directive* force upon the earth plates, and was arranged thus:—A circle 40 ft. in diameter was described, and the chief points of the compass carefully staked upon it. Two poles were sheathed with clean copper at their lower extremity, the copper being connected to the experimenting room by means of loose covered wires. The sheathed ends of the poles were driven into the moist earth to a depth of two feet. Starting with the poles at opposite points —N and S—upon the circle a careful observation was made, and the slight but clearly discernible oscillations of the "spot" were noted. Similar observations were repeatedly made with the poles at each pair of opposite points, but without leading to any trace of directive effect, both variation and amplitude being pretty much the same all round the circle, and the idea of earth-current connection was, for the time being, given up. The

fact had, however, been elicited that these variations were in a slight degree obtainable from *earths* that were comparatively near one another, although when very near the effect upon the apparatus ceased. Prior to dismantling the arrangement the following experiment was tried:—Two pairs of earth plates were buried thirty feet apart, the respective plates of each pair being three feet apart. Upon joining either pair through the galvanometer no variation effect was observable, but when either plate of one pair was joined through the galvanometer to either plate of the other pair slight oscillations of the spot became apparent, indicating, it would seem, that at least some extent of the earth crust between a pair of earth plates is necessary in order to obtain these effects.

The remarks submitted here are not intended as a solution of this phenomenon, for it will be apparent that many important experiments await trial; but it is thought that the importance of the subject in its relation to long-distance telephony, and to the more sensitive systems of telegraphy, is such as to deserve a larger share of attention than it has hitherto received, and, further, that these results, which seem to point to a variation in the conducting power of the earth itself—locally, perhaps—warrant a more thorough and continued course of investigation than is within my own reach. It would be of interest also to know if and how far this variation is related to the sound disturbances heard from a buried microphone.

ON THE ENERGY OF FUEL IN LOCOMOTIVE ENGINES.

By GRANVILLE CARLYLE CUNINGHAM, M. Inst. C. E.

Selected Papers of the Institution of Civil Engineers.

THE object of this paper and of the accompanying table, is to show, by data obtained from different railway companies, what is the amount of fuel consumed per unit of work done by locomotive engines; how this consumption varies in different lines of railways; and how the energy of the fuel utilized compares with the full energy, in other words, how much of the energy is used, and how much lost.

The consumption of fuel per unit of work, that is, per ton weight moved one mile, is perhaps the most certain and reliable scale by which the capacity of a railway for doing work can be measured, and compared on the same scale with another railway. Any estimate based upon cost is misleading, since the price of labor, fuel, and everything that enters into the working of a railway, varies at different times and in different places. It might thus happen that a line showing a large cost per train-mile, or per car-mile, was more economically and carefully worked, and better able to do the work for which it was constructed, than another showing a smaller cost per car-mile. The comparison plainly depends upon the cost of labor and material in the two localities, and is vitiated by the rise and fall of markets. No true comparison of the respective railways, or even of different periods of the same railway, can be made until such vitiating elements have been eliminated, and a basis arrived at which shall be common to each, and unaffected by any adventitious circumstances. In the consumption of fuel per unit of work there exists such a common basis of comparison, and one which demonstrates the capacity for doing work which the railway possesses. For the consumption of fuel is almost an absolute standard, varying only with the quality of the fuel used, and is not affected by any other uncontrollable circumstance. Thus, if on one line of railway the consumption per ton moved one mile is very much greater than on another, it is evident that on the former the gradients and curves, and such elements of resistance, must be more severe than on the latter; and that therefore the latter line is the better able to do its work, and can, other things being equal, do it more cheaply. Of course other circumstances may cause

an unusual consumption of fuel, such as severity of climate, inducing large evaporation and loss of heat; or badly-designed engines, resulting in waste of fuel. But even these are matters that can be controlled, because the first may be obviated by having the engine more thoroughly protected from the weather, and the second by improvements in the type of engine. With similar engines acting under not very dissimilar climatic influences, it remains that the consumption of fuel per unit of work may be taken as a certain index to the character of the railway.

In preparing the table which accompanies this paper, considerable difficulty has been experienced in arriving at the requisite data. The published annual reports seldom give the information in the direct manner in which it is required; but all the figures made use of have been drawn either from the published reports, or from information obtained directly from the railway officials.

On the Canada Southern Railway, where the consumption of fuel is lower than on any of the other lines, the gradients and curvature are very light. The main line of this railway extends through the southern part of the Province of Ontario in Canada, from Fort Erie on the Niagara River, where the International Bridge gives access to the State of New York, and opposite to the City of Buffalo, to Amherstburg on the Detroit River, separating Ontario from the State of Michigan. The Detroit River is crossed by ferry-boats, on which the carriages are taken over to Grosse Isle; from whence they run into Toledo (where connection is made with the Wabash railway system), or into Detroit (where connection is made with the Michigan Central system), over the Toledo, Canada Southern and Detroit Railway. The distance from Fort Erie to Amherstburg is 229 miles, and throughout there is no gradient steeper than 15 feet to the mile (1 in 352), and the alignment is remarkably free from curves. On the western portion of the line, the distance from St. Clair Junction to Amherstburg, 107 miles, is made up of two straight lengths of 53 and 54 miles, joined by a light curve. The same gradient is maintained on the Toledo, Canada Southern and Detroit Railway, and on the St. Clair branch of the main line. The only parts of the system on which steep gradients exist are the Erie and Niagara, and Michigan Midland lines; but on these the traffic is extremely small, and they aggregate only 45.28 miles in extent, as compared with 403.64 miles of the entire system. The locomotives used are of the Baldwin type, with two pairs of driving-wheels coupled, and weighing about 60,000 lbs. on the drivers.

The main line of the Michigan Central Railroad, which extends through the southern part of the State of Michigan from Detroit to Chicago, is 284.07 miles in length, but with branches and leased lines, it comprised 949.59 miles in 1881. The gradients on the main line and branches are considerably steeper than those on the Canada Southern, and in places reach 52 feet to the mile (1 in 100). The locomotives used are similar to those on the Canada Southern, and the fuel is also similar, being bituminous coal from Ohio.

The Lake Shore and Michigan Southern Railway extends along the southern shore of Lake Erie from Buffalo to Chicago, with branches to Detroit and other places. The total mileage of the system in 1880, including leased lines, was 1,177.67, and of this the length of main lines is 504.49 miles. The gradients of the main line are considerably easier than those of the Michigan Central, and nearly as good as those of the Canada Southern Railway. The engines and fuel are similar to those on the lines beforementioned.

The Hannibal and St. Joseph Railroad is in the State of Missouri. Its mileage in 1880 was 292.35. From the length of trains hauled, the gradients would seem to be steep.

In preparing the table in the Appendix, information has not always been obtainable from the printed reports in the exact form required. In these cases the method adopted for supplying the particulars has been as follows. The total amount of coal and wood (the latter turned into its equivalent in coal) consumed is noted. When the amount to be apportioned of the freight and passenger services respectively is not stated in the printed report, the total amount is divided into two portions in the ratio of the respective engines, mileage, and also in the ratio

of 26 to 34, being that in which the consumption of a passenger-engine, as determined by careful observation, stands to the consumption of a freight-engine. This, in the first instance gives the total amount of coal consumed in each service, including switching or shunting. In order to arrive at the amount consumed in moving freight-trains on the line, the total amount of engine mileage made in switching or shunting is noted, and this is divided into two portions, in the proportion in which the passenger-train mileage stands to the freight-train mileage, and the switching is thus allotted to the respective services. The coal consumed in the service is then calculated by allowing 70 miles per ton, and the quantity thus obtained is deducted from the total quantity apportioned to the freight service. This estimate of 70 miles switching per ton of coal consumed is taken from the observations of the Lake Shore and Michigan Southern Railway, extending over a number of years. It will be seen, therefore, that the results obtained are only close approximations to the absolutely true figures of this subject; but still they are sufficiently close to be valuable as comparisons.

The table shows that the coal consumed in passenger traffic is less on the Lake Shore line than on any of the others, being, 12.8 lbs per passenger-carriage mile. Taking the average weight of the cars composing the passenger train at 16 tons, this would give a consumption of 0.8 lb. per ton hauled 1 mile; at the same time it is interesting to note that there is a consumption of 1.16 lb. per passenger moved 1 mile. The very large consumption of fuel per ton moved 1 mile in the passenger service, as compared with the freight-service, is undoubtedly due to the much higher rate of speed of the former, as compared with the latter. Confirmation of this is found on considering the figures applicable to the Hannibal and St. Joseph line. There the consumption per ton-mile in the passenger-service is less than that of either the Canada Southern or Michigan Central, and only very little greater than that of the Lake Shore line; whereas the consumption per ton-mile in the freight service of the Hannibal and St. Joseph line is very much greater than any of the others, being more than double that of both the Canada Southern or Lake Shore lines. This apparent anomaly is explained by the fact that the speed of the passenger trains on the Hannibal and St. Joseph line is much less than that on any of the others under consideration.

The consumption of fuel in freight-service on the Canada Southern and Lake Shore lines is nearly the same, with a small fraction in favor of the former, while on both lines it is less than on the Michigan Central, or Hannibal and St. Joseph. The amount of fuel consumed in moving 1 ton gross weight (including the fuel consumed in shunting) is barely $2\frac{3}{4}$ ozs.—a quantity which is surprisingly small. This is on the two first-mentioned lines; while on the Michigan Central and Hannibal and St. Joseph lines it amounts to 4 ozs. and 6.4 ozs. respectively.

In the latter part of the Table the amount of coal consumed in the switching or shunting work of the freight service has been deducted, and that consumed in the work of moving freight-trains on the line of railway only dealt with, with a view of arriving at the quantity consumed in moving 1 ton weight 1 mile. The result arrived at is as follows: Canada Southern, 2.30 ozs.; Lake Shore, 2.38 ozs.; Michigan Central, 3.52 ozs.; and Hannibal and St. Joseph, 5.76 ozs.

Though it will surprise most people who have not paid particular attention to these questions, to learn that there is sufficient energy in a piece of coal weighing only 2.3 ozs. to move one ton weight one mile; yet the investigations would not be complete if it were not ascertained what is the total energy of the fuel; what portion of it is used, and what lost.

The units of heat (Fahrenheit) developed in the combustion of 1 lb. of coal are 14133,* and as the mechanical equivalent is 772 foot-pounds per unit, the combustion of 1 lb. of coal is equal to 10,910,676 foot-pounds, or 5455.3 foot tons (American).

On the Canada Southern Railway, the average of the whole line is equal to a gradient of 5 feet to the mile; this will make the resistance to haulage equal to 11 lbs. per ton, taking the resistance on the level at 9 lbs. per ton; therefore as much energy will be expended in hauling 1 ton 1 mile, as in lifting 11 lbs. 1 mile

* "A Manual of Rules, Tables, and Data, &c.," by D. K. Clark, M. Inst. C. E., p. 405.

APPENDIX.—TABLE SHOWING CONSUMPTION OF FUEL ON VARIOUS RAILWAYS.

	Canada Southern	Michigan Central.		Hannibal and St. Joseph.		Lake Shore and Michigan Central
	1881.	1879.	1880.	1879.	1880.	1880.
Total engine mileage (including shunting)	3,749,701	7,697,051	7,690,051	—	1,995,739	13,586,207
Passenger train-mileage	987,237	1,693,098	1,865,258	414,118	410,368	2,549,081
Passenger car-mileage	4,196,466	8,499,352	10,333,529	2,190,243	2,239,970	16,060,832
Average number of cars per passenger train	4.25	5.02	5.54	5.28	5.45	6.30
Number of passengers moved 1 mile	40,917,987	93,232,430	115,523,789	21,545,368	19,925,041	176,148,767
Average passengers per car	9.75	10.96	11.18	9.83	8.89	10.96
Freight train-mileage	1,775,237	3,687,305	3,658,605	938,095	975,603	7,481,489
Freight car-mileage	56,915,859	88,384,701	88,491,897	15,715,882	16,864,202	283,588,545
Average number of cars per freight train	32.06	23.97	24.16	16.75	17.28	37.90
Number of tons of freight moved 1 mile	487,965,507	721,019,413	735,611,995	111,987,174	120,665,740	1,851,166,018
Average load per freight car.....tons.	8.57	8.166	8.31	7.13	7.15	6.52
Total amount of coal consumed.....tons.	127,270.5	280,160	303,971	69,990	76,898	502,320
Tons of coal apportioned to passenger service	38,072	75,250	84,078	15,190*	17,491*	102,837
Pounds of coal consumed per passenger train-mile	77.12	88.88	90.15	73.11	85.24	80.68
Pounds of coal consumed per passenger car-mile	18.14	17.70	16.27	13.84	15.63	12.80
Pounds of coal consumed per ton moved 1 mile	1.13	1.10	1 01	0.86	0.98	0.80
Pounds of coal consumed per passenger moved 1 mile	1.86	1.61	1.45	1.31	1.75	1.16
Tons of coal apportioned to freight service	89,198	204,910	219,893	54,800*	59,407*	399,483
Pounds of coal consumed per freight train-mile	100.49	111.17	120.20	116.83	121.77	106.78
Pounds of coal consumed per freight car-mile	3.13	4.64	4.97	6.97	7.04	2.81
Pounds of coal consumed per ton of freight moved 1 mile.	0.367	0.57	0.60	0.98	0.99	0.43
Pounds of coal consumed per ton of gross weight†	0.168	0.25	0.27	0.40	0.41	0.17
Average miles run by engines per ton of coal	29.46	27.47	27.47	—	25.95	27.04
Total expenses (exclude renewals and taxes).....$	2,550,223.11	—	—	1,223,421.97	1,304,590.08	—
Passenger expenses (exclusive renewals and taxes).....$	584,148.13	—	—	414,150.20	439,295.75	—
Passenger expenses per train-mile.....$	0.59.17	—	—	1.01	1.07	0.92.29
Passenger expenses per car-mile.....cents.	13.92	—	—	18.9	19.6	14.65
Freight expenses.....$	1,966,074.98	—	—	809,271.77	865,294.33	—
Freight expenses per train-mile.....$	1.1075	—	—	0 863	0.887	1.0767
Freight expenses per car-mile.....cents.	3.45	—	—	5.15	5.13	2.84
Average expenses of tons of freight moved 1 mile...cents.	0.40	—	—	0.72	0.72	0.43
Coal consumed in freight shunting alone.....tons.	9,025	22,698	20,945	—	6,122	35,282
Coal consumed by freight-trains alone.....tons.	80,173	182,212	198,948	—	53,285	364,201
Coal consumed per freight train-mile .....lbs.	90.32	98.8	108.7	—	109.23	97.36
Coal consumed per freight car-mile.....lbs.	2.81	4.12	4.5	—	6.32	2.57
Coal consumed per ton of freight moved 1 mile.....lbs.	0.32	0.50	0.54	—	0.88	0.39
Coal consumed per gross ton moved 1 mile..... lbs.	0.15	0.23	0.24	—	0.37	0.155

* These quantities are found from the value of fuel apportioned to the passenger and freight traffic in the Annual Report. † Weight of the cars is assumed at 10 tons each.

vertically. In other words, hauling 1 ton 1 mile requires an expenditure of energy equivalent to $5{,}280 \times 11 = 58{,}080$ foot-pounds, or 29.04 foot-tons.

But on the Canada Southern Railway, 1 ton is hauled 1 mile by the combustion of 0.15 lb. of coal, which quantity of coal therefore does work equivalent to raising 29.04 tons 1 foot. At the same rate 1 lb. of coal would raise 193.6 tons 1 foot vertically. But as shown above, the full energy of 1 lb. of coal is 5,455.3 foot-tons; therefore the full energy is to the work effected on the Canada Southern Railway as 100 is to 3.5, and consequently there is a loss of 96.5 per cent. of the energy of the fuel. Though the quantity, 2.3 ozs. of coal, seems extremely small to do the work of hauling 1 ton 1 mile, yet, if all the energy contained in the coal could be utilized and applied to doing work, it would haul 1 ton 28½ miles; while the quantity, 1.86 lb., consumed in moving a passenger 1 mile would, if fully utilized and applied to the transportation of freight, convey 1 ton 353 miles. Few passengers are aware of how much energy is required to make "fast time."

The speed of passenger trains on the Canada Southern Railway was from 35 to 40 miles per hour; on the Michigan Central and Lake Shore lines from 33 to 36 miles per hour; and on the Hannibal and St. Joseph line about 25 miles per hour. The speed of freight trains on all the lines was between 15 and 20 miles per hour.

The position of acting Chief Engineer, which the author until recently occupied on the Canada Southern Railway, enabled him to obtain the information in regard to gradients required to make the foregoing investigations; but the like information has not been obtainable for the other railways under consideration, and therefore it is not possible to say whether they waste more or less of the energy of the fuel consumed. A comparison on a similar basis with English railways would be interesting and valuable, but the necessary data do not seem to be available. These figures clearly indicate how much yet remains to be done in economizing the energy developed in the combustion of coal. An engine which wastes 96½ per cent. of the energy with which it is supplied cannot be called perfect.

The table also shows the cost of the service performed, worked out in a similar manner as the consumption of fuel.

CORRESPONDENCE—KUTTER'S FORMULA.

To the Editor of VAN NOSTRAND'S MAGAZINE:

Mr. Flynn's criticism of my modification of Kutter's formula for pipes has just reached me. Mr. Flynn is quite correct. The formula as it stands in page 25 of the twenty-first edition of my pocketbook has an omission of $\sqrt{d}$. As I had originally framed it, it stood thus:

$$C = \frac{181 + \frac{00281}{S}}{1 + \frac{.026}{\sqrt{d}}\left(.41.6 + \frac{00281}{S}\right)}$$

Unfortunately the omission of the $\sqrt{d}$ escaped my observation in correcting the proofs of this twenty-first edition.

Taking the side cases which Mr. Flynn has worked out, a comparison of Kutter's formula and my modification of it for pipes, as corrected, stands thus:

Diam. of pipe.	Slope 1 in 1.	Kutter.	Molesworth.
6 in.	40	71.50	71.48
6 in.	1000	69.50	69.79
4 ft.	400	117.00	117.00
4 ft.	1000	116.5	116.55
8 ft.	700	130.5	130.68
8 ft.	2600	129.8	129.93

The two formulæ are thus far substantially identical in results though differing slightly in form.

GUILFORD MOLESWORTH.

SIMLA, India, May 17, 1886.

ENGINEERING NOTES.

A POCKET HELIOGRAPH.—A pocket heliograph or optic signaller has been brought out by Dr. E. Gavoy, and introduced into the French military telegraph staff by the Minister of War. It consists of two copper tubes of five centimetres in diameter, sliding one within the other. The upper tube carries a plane mirror, inclined at an angle, and throwing off the light of a lamp, or the sun reflected up to it from an adjustable mirror in the lower tube. The light thus thrown off passes along a short tube at right angles to the upper part of the main tube, and in doing so traverses two lenses, one plano-convex the other double convex. Between these two lenses is an adjustable shutter, by which the rays are occulted so as to make the signals. An oil lamp, with reflector to throw its rays on the lower mirror, is added to the apparatus in such a way that it shuts up within the lower tube under the lower mirror. A lunette to indicate the path of the rays through the air to the distant observers is also fitted to the top of the apparatus. According to trials recently made in the park of Versailles, the apparatus worked satisfactorily over distances of from 1000 to 1200 metres.

WOOD TURBINE WATER WHEELS.—In some portions of Europe, turbines constructed of wood and iron have been made to a limited extent, but the writer once saw a turbine con-

structed entirely of wood. The southern portion of the Appalachian range of mountains, in the United States, juts into the northern portion of those States bordering on the Gulf of Mexico, and the western portion of the States forming the Atlantic coast. This region consists of a plateau broken up by high mountains, and is a most fertile country, sparsely inhabited by a primitive people, descended from the early English settlers in the southern portion of the American colonies; but this country possesses no navigable rivers, and has not been traversed by the railroad, and has therefore been isolated from the rest of the world. Words and forms of expression are there used which have been obsolete in the English language for at least a century. The writer, while on a horseback trip among these mountains in 1881, saw a man, near one of the little grain mills, working on what appeared to be a foundry pattern. On asking a few questions, it was learned that this miller, while on a trip to a manufacturing town near to the sea shore, saw a water-wheel taken up for repairs in one of the mills, and remembered enough to make a Boyden wheel, carving it from a sycamore log.

THE opening of the canal, which has been in process of excavation for the past five years for the purpose of draining Lake Copais, was celebrated on Saturday last in presence of the French Minister and numerous distinguished persons from Athens. Lake Copais, which is situated near Thebes, in Bœotia, covers an area of over 60,000 acres, or nearly 100 square miles. The French Company which has been engaged in carrying out the enterprise is now so far advanced with its work that two-thirds of the waters of the lake are expected to be drawn off within the next two or three months. Hitherto this inland sea has been chiefly remarkable for the malaria and fevers regularly prevailing on its shores during the hot season. By its drainage, not only will this evil be permanently removed, but Greece will add to her territory many thousands of acres of arable soil of the greatest fertility. The lake is fed by the rivers coming down from Mount Parnassus, whose waters are hereafter to be employed, by help of a new system of canals, in irrigating the surrounding country.

RAILWAY TUNNELS IN RUSSIA.—Although Russia has built over 15,000 miles of railway, the longest tunnel she has had to construct up to this year has only been 700 yards long. On this account the vote last week by the State Council of £700,000 to construct a tunnel three miles long on the Suram loop line, possesses for Russia extreme importance. To all intents and purposes her railway engineers are practically ignorant of tunnel making, and to carry out the Suram undertaking the advice of foreign experts has had to be sought. Simultaneously with this, a tunnel 1400 yards long will be taken in hand on the Novorossisk Railway, in the Kuban region of Cis-Caucasia. This will be twice as long as any existing tunnel in Russia. For the most part the tunnels already made are on the Lozova-Sebastopol, Warsaw, Ivangorod-Dombrova and Transcaucasian railways—that is to say, all the outskirts of Great Russia proper, being situated in Poland, the Crimea, and the Caucasus. Elsewhere, there are no tunnels at all, and but very rarely bridges across railway cuttings. Probably in the metropolitan area there are more bridges and tunnels than in the whole Russian empire. Thanks to this circumstance Russia is able to move some of her military and naval resources about in a manner hardly appreciated by English strategists and statesmen. Thus, during the Turkish war, she took steamers off the River Neva, placed them on trucks and sent them by rail with the greatest facility, to the Black Sea and the Danube. Only a few months ago, she shifted at a stroke fifty torpedo boats in this manner from the Baltic to the Black Sea. Yet in spite of all this, there were actually certain feather-brained generals at the War Office last year, who proposed during the war scare, that England should seize Batoum and the Transcaucasian Railway and send across the latter steamers in segments, to be fitted together at Baku to fight the hundreds of steamers Russia already possesses in the Caspian and Volga, and the scores she could have sent at once, ready made and fit for action, by railway in the manner we have described, from the Neva and other rivers to the Volga! Perhaps the War Office is a little bit wiser now and has pigeonholed for good a plan which would have exposed every English steamer placed on the Caspian to a ridiculously hopeless contest. It may be noted that now the Russian railways have commenced spreading in the Caucasus, a deal of tunnelling will be encountered. On the direct St. Petersburg-Tiflis line, at present broken by a short gap from Vladikavkaz to Tiflis, a tunnel eight miles long has been planned for years, piercing the main bridge of the Caucasus. There is hardly a doubt that this will be taken in hand after the completion of the Suram tunnel.

IRON AND STEEL NOTES.

A NEW PROCESS OF ROUND FORGINGS.—Mr. George H. Simonds, of Fitchburg, U.S.A., has invented a machine for the purpose of forging iron or steel in any form which can be turned. This involves an entirely new method of working iron. Instead of being hammered or rolled to the desired form, the mass of red-hot metal is placed in a groove in two plates which are moved in reverse directions; the grooves are in primitive form at the places where the iron first enters between the plates, and along its course these grooves become more closely in conformity to the shape which is given to the finished piece, which is twisted into shape. The process is applied with success to the manufacture of conical shot, forged out of steel, the British Government having given an order for 500,000 shot, which are being made by the English representative. This process is applied to the manufacture of any small iron or steel pieces of turned form.

THE DIRECT PRODUCTION OF STEEL.—The direct production of steel from the ore is a subject which has long attracted the attention of metallurgists and others, and several at-

tempts have been made to solve the problem. The latest proposition in this connection is that of Mr. James J. Shedlock, of 9 Gracechurch street, London, which comes to us with a degree of individuality and hopefulness not usually met with in such inventions, and this by reason of its being a distinct departure from previous practice. The principles involved in Mr. Shedlock's process consist in the use of reducing gases produced by the decomposition of steam in conjunction with a bath of molten metal, which he employs to take up the metals as they are reduced from their combinations. The problem of thus releasing metals from their ores without liquefying the matrix, and therefore without using fluxes and resorting to high temperatures, has had long and careful study at the hands of Mr. Shedlock, who has been working at it for the past twelve years. Having proved it over a wide range of metals, he has at length brought it to that point at which demonstration on a practical commercial scale need be no longer delayed. To this end extensive premises have been taken at Blackwall, and machinery and smelting apparatus put up there for carrying out the process, and which we recently inspected. The works have a frontage of 190 feet on the River Thames, and railway communication is close at hand. The apparatus is of exceedingly simple character, and the plant now laid down is calculated to smelt about 25 tons of ore per day; but there is ample room for more than quadrupling the present appliances and rate of output.

Mr. Shedlock's method of treating ores for the separation of their metals is carried into effect by passing the ore in a finely divided state through a bath of molten metal maintained at the temperature necessary to insure its combination with any free metal contained in the ore. But as most ores contain metals associated or in combination with the metalloids, it is necessary to decompose such compounds in order that the metals may be freed and in such a condition as to readily combine with the metallic bath.

This is accomplished by forcing streams of reducing gases through the bath of molten metal simultaneously with the pulverized ore, which is conveyed into the bath at one end by feeding apparatus, the action of which is so regulated as to work in concert with the supply of reducing gases. For the production of these gases, steam is passed through superheaters, the outlets of which communicate with gas producers, which produce carbonic oxide and hydrogen gases, which are conveyed from the producers by tubes into the bath of molten metal at the point of entry of the powdered ore.

In consequence of the affinity possessed by these gases for the metalloids, and also by reason of their high temperatures, the metallic compounds are decomposed and the volatile constituents of the ore are vaporized, which, with the earthy or non-reducible portions, by reason of their lesser specific gravity, rise to the surface of the bath of molten metal. The gases and vapors are conveyed through flues into chambers where those that are condensable are thrown down and collected, the permanent gases escaping into the chimney shaft, and the earthy matters being removed from the end of the bath opposite the feeding end by skimming. The metals as they accumulate in the bath overflow into receivers through spouts, the inner mouths of which are so much below the surface of the metal as to prevent any dross from passing over. The metals as they collect are run into ingots or bars.

In treating some ores, more particularly those containing the noble associated with the baser metals, it may be found desirable to refine those metals without removal from the bath. For this purpose atmospheric air raised to the required temperature is forced through the molten metals in the bath, its passage being retarded by an inclined cover, thereby causing agitation of the mass and subjection of the metals and metalloids to the oxidizing action of the heated air. The oxides and other combinations thus formed with the vapors and gases rise to the surface, and are conveyed by the flues to the condensing chambers, the refined metal being withdrawn from the bath and run into ingots. The superheaters, gas producers, and air heating chambers are inclosed in a firebrick structure, into which the heated products of combustion from the furnace enter and circulate, thus raising the temperature of the apparatus and its contents to the required degree.

The furnace gases then pass into the flues surrounding the bath containing the molten metals, eventually escaping into the chimney shaft. According to Mr. Shedlock, there are no exceptions to the ores which may be manipulated by his invention, the most refractory as well as the most easily reduced being successfully treated by its means. The ores of iron, when subjected to the process for the extraction of that metal, are stated to be most readily reduced, and its direct conversion at one operation into the different carbides of iron, varying from the softest cast iron to the mildest steel, easily accomplished; at the same time, all deleterious impurities are said to be effectually removed. The ores of zinc are also readily treated by this process as a continuous operation, the ore being fed into the apparatus, and the metal as it is distilled over passing away through the flues into the chambers, where it is condensed and collected. Should the process be as successful an operation on the large scale as is anticipated, we may expect an increased supply of gold, as by its means the most refractory ores of gold may be treated. By the ordinary system of separating gold from its ores, it is acknowledged that not much more than 50 per cent. of the gold present is recovered. The details of the invention, as well as those of the apparatus by which it is to be carried into practical effect, have been carefully thought out, and the reasonableness of the modus operandi gives every hope of its commercial success. The works will shortly be running, and after some hundred tons or so of stuff have been put through—which Mr. Shedlock very properly holds is the only fair test of the capabilities of his invention—we shall report progress, in the meantime wishing the process every success.—*Iron.*

RAILWAY NOTES.

MESSRS. BOLCKOW, VAUGHAN AND CO., Middlesbrough, have secured an order for nearly 10,000 tons of steel rails for the Swedish and Norwegian Railway Company. This, with the rails on hand, is sufficient to complete the 200 kilometres of the company's line from the great iron mountain of Gellivara to the port of Lulea. This iron ore in inexhaustible quantities contains 70 per cent. of metallic iron. The company hopes to lay this section of the line this year, and it is taking delivery of 1000 tons of rails per fortnight.

SWEDISH RAILWAYS.—The length of the railways of Sweden at the end of 1885 was nearly 3,000 miles, half of which belonged to the state, the total gross receipts being £2,110,000, or £700 per mile, £1,100,000 of which were earned by the state lines. Concessions were granted to private companies for 95 miles of new lines, whilst 180 miles of private and 10 miles of state railway were opened for traffic during the year.

CANADIAN RAILWAY PROGRESS.—The following percentages of increase in the railway system of Canada during the last ten years indicate also very clearly the development of the country during that period. The miles of completed railway have in ten years increased 118 per cent., the amount of capital invested has increased 48 per cent., the gross earnings show an increase of 66 per cent., and the net earnings an increase of 130 per cent. The number of passengers carried increased 76 per cent., the amount of freight 130 per cent., and the train mileage 70 per cent.

THE St. Gothard Tunnel line was opened for traffic on the 1st of January, 1882. Since then Germany has increased the value of her exports to Italy from 66,000,000f. to 110,000,000f., and to Spain—by Genoa—from 51,344,000f. to 86,679,000f. As for Switzerland, in 1881 her exports to Italy were valued at 37,000,000f.; they have now risen to over 75,000,000f. Italy has benefitted even more. Her exports to Switzerland, Germany, and Belgium have risen by leaps and bounds, and the commerce of the port of Genoa in particular has increased since the St. Gothard line was opened by 50 per cent. What Italy has gained France has lost. Merchandise from the North wishing to reach the Mediterranean is being more and more sent to Genoa instead of Marseilles The former port, thanks to the St. Gothard line, has the advantage in distance over Marseilles as follows:—From Antwerp, 76 kilometres; Ostend 34; Charleroi, 66; Brussels, 76; Namur, 127; Amsterdam, 139; Utrecht, 162; Cologne, 259.

ENGLISH capitalists are looking to Holland as a field for railway enterprise. Holland has an area of 12,680 square miles, and a population of some 4,300,000 inhabitants, but possesses only about 1100 miles of railway. The waterway system has hitherto provided sufficient means of locomotion to meet the wants of trade and commerce. A company called the English-Dutch Light Railways Company proposes to utilize the existing public roads for light railways or tramways, for goods as well as passenger business, and for working by steam. The gauge proposed is 3ft. 6in., and the first line to be built is from Breda—a junction for Rotterdam, the Hague, and Amsterdam—to Oudenbosch and to the frontier of Belgium—a distance of about 23 miles. The Société des Chemins de Fer Vicinaux has arranged to make a similar line from Antwerp to the frontier, simultaneously with this one, so that there will be uninterrupted communication between Breda and Antwerp. The second line is proposed to run from Druten through Wychen, passing through many thriving towns and communes to Gennep, a distance of about 29 miles.

ORDNANCE AND NAVAL.

OUR NEW NAVY.—It is understood that Secretary Whitney will in a few days invite proposals for building the four steel war vessels recently authorized by Congress. One of these vessels is to be 800, one 1,700, and two 4,000 tons each. The Secretary has been severely criticised for purchasing abroad the plans of the 4,000-ton steel vessel lately built by Armstrong for the Japanese Government, but all American shipbuilders who have examined these plans cordially approve them The vessel in question combines the most advanced ideas of naval architecture, the results of several years of actual experiment, and the vessel is a complete success, having made within a small fraction of nineteen knots at sea. The plans of this vessel have been open to the examination of all American shipbuilders, and it is unanimously agreed that the Secretary did a wise act in purchasing the plans and placing them on exhibition for the benefit of our shipbuilders. It is probable that these plans will be adopted in the construction of the four cruisers, and that the two 4,000-ton vessels will be exact copies of the ship built by Armstrong for the Japanese Government. The Acting-Secretary of the Treasury has sent to the Senate a letter from the Secretary of the Navy submitting a request for an appropriation of $186,998 to complete the three steel cruisers, Chicago, Boston, and Atlanta, and to pay the amount due on the dispatch boat Dolphin. He says work on the vessels in course of construction at Mr. Roach's yards must be discontinued, and the final payment on the Dolphin can not be made, thus causing much embarrassment to the Government and Mr. Roach's assignees.—*Bulletin.*

TANK STEAMERS ON THE TYNE.—According to an authoritative statement in the *Newcastle Chronicle*, "the workmen at Messrs. Hawthorn & Leslie's shipyard, at Hepburn, will be shortly engaged both day and night, arrangements having been completed for making five vessels into petrolum tank steamers," in consequence of which "a number of the unemployed in Hebburn and Jarrow will probably be restarted." This is an eminently satisfactory announcement, and we trust that now a commencement has been made in a direction persistently advocated since 1883, we shall hear of other proofs of similar activity in the north.

It may be remembered that on the return of the traveler, Mr. Charles Marvin, from Baku, in 1883, he drew attention in his "Petroleum Industry of Southern Russia" to the astonishing success of the tank steamers in the Caspian Sea, and urged that English shipowners should apply to the ocean generally what Messrs Nobel had introduced on the Caspian and Volga. His arguments seemed to us sound, and repeatedly, during the depressed period of last year, we recommended the matter to English shipowners, particularly as the revolution in the mode of transport involved a vast amount of activity, of which a rough estimate could be formed from the single fact that in the Caspian alone the petroleum trade had called into existence 80 new tank steamers for a supply not one-sixth as large as that of the United States. In the interests of the very large number of men out of employ, it is a pity, perhaps, that the task of constructing tank steamers for the Atlantic petroleum trade was not commenced earlier; but, all the same, we are very glad English shipowners have thoroughly assimilated the idea at last. Speaking at a lecture on petroleum before the Blackheath and Lewisham Scientific Society a fortnight ago, Mr. Martell, chief surveyor of Lloyd's, said that he was "almost daily having inquiries addressed to him by shipowners and others with reference to these tank steamers." We mention this because it is only now that English shipbuilders are admitting, by the construction of these steamers, that this two years' advocacy of their interests was not misplaced, and because we wish them to realize that the American petroleum trade will want at least a couple of hundred of these steamers before the requirements of bulk transport are in any way properly satisfied.

THE NORDENFELT GUN.—A highly interesting and important series of experiments was recently carried out at Dartford with several patterns of the Nordenfelt gun. The experiments were divided into two parts, the first comprising trials with single and multiple-barrel rifle-calibre guns and the two-barrel 1-inch gun, whilst the second included quick-firing guns. Experiment I. was with a single-barrel rifle-calibre gun, mounted on a field carriage, and which was fired for 30 seconds, 80 rounds being got off in that time. Experiment II. was with the 3-barrel rifle-calibre gun, also mounted on a field carriage. At the start, only a couple of rounds were got off when a hitch occurred, and on examination it was found that the cartridges were supplied of a wrong pattern for the gun. Nothing daunted, Mr. Nordenfelt had a second gun run up, from which 87 rounds were got off in 20 seconds. Attention was then turned to the 5-barrel rifle-calibre gun mounted on an infantry carriage, with which two hoppers containing 100 rounds were fired in 13 seconds. The same gun was then fired for 30 seconds, during which 265 rounds were got off. The 10-barrel rifle-calibre gun, mounted on a naval carriage, then fired 200 rounds in 13 seconds, after which it was fired for 30 seconds, during which 400 rounds were got off. Experiment V. was with a 5-barrel rifle-calibre gun mounted on a carriage, intended for use in the tops. The gun was placed on a high bank commanding the range, and fired with a depression of 55°, 200 rounds being got off in 13 seconds. The sixth and last experiment of the first series was with a 2-barrel 1-inch gun mounted on a naval carriage. With this gun 20 rounds were fired in 5½ seconds, after which it was fired for 30 seconds, including the time for changing the hoppers, when 76 rounds were got off. The proceedings were then varied by drill by a detachment of the Central London Rangers Machine Gun Club, under the command of Lieutenant Fielder, with a 5-barrel Nordenfelt gun on an infantry carriage, at which point proceedings were stayed for luncheon, which, after the heat, dust and smoke, was by no means unappreciated.

On resuming, experiments for penetration were commenced with quick-firing shell guns, the first tried being a 1-inch gun, firing a solid steel shot with a hardened point—not chilled, but tempered just as a chisel or a turning-tool is tempered. The Nordenfelt shot, as also the shell, are all turned out of the solid, and have their points thus hardened. The 1-inch gun was laid against a 1-inch wrought-iron plate, the range in all cases being 190 feet. The shot went clean through the plate and wood backing. The 1½-inch 2-pounder shell gun was then fired with a solid projectile against three 1-in. wrought-iron plates clamped together, the projectile embedding itself in the three plates, and showing a bulge at the back of the rear plate. A second round was fired from this gun, with similar results. The 6-pounder shell gun was then laid against five 1-inch wrought-iron plates leaning against each other at a slight angle against the wood backing, with slight spaces between them, that between the third and fourth plates being 1 inch. Taking the spaces and angle into consideration, the plates may be said to represent a 6-inch target, and through this and the timber backing the shot passed splendidly, the plates being held together after the shot by the burr passing from the rear of each plate to the face of the next. This was distinctly seen in the 1-inch space between the third and fourth plates. Tests for rapidity of fire were then made with the shell guns, the first tried being the 3-pounder shell gun mounted on a field non-recoil carriage. With this gun three rounds were first fired slowly, in order to show the working of the carriage, which did the most effectually, after which six rounds were fired in 13½ seconds for rapidity and accuracy of fire. The six-pounder shell gun, mounted on a recoil carriage, then fired 6 rounds in 15 seconds, after which the 1½-inch shell gun, mounted on a naval non-recoil carriage, fired 6 rounds in 17 seconds.

The visitors then witnessed drill by a detachment of the 2d Battalion of the Grenadier Guards, under Captain Lloyd, with a Nordenfelt 5-barrel machine gun mounted on an infantry carriage. The drill was very good, and afterwards the gun was brought up at the double over rough ground to the range, where volley firing and single-firing was performed with an excellence that elicited the approval of

all. The third and final drill was by a detachment of the 10th Hussars, under Major Wilson, with a Nordenfelt 5-barrel rifle-calibre machine gun, mounted on an improved Beresford galloping carriage. Some very effective work was done with this carriage, which was put through some heavy drill with excellent results, and was afterwards run up over a sharp bank on to the range and fired. Mountings for machine guns for camels and mules were shown, the latter animals being packed and satisfactorily put through their paces. The day's proceedings were in every way successful, and demonstrated the variety, efficiency and usefulness of the Nordenfelt machine gun, against which torpedo boats would stand but a poor chance.

BOOK NOTICES.

THE NAVAL BRIGADE, AND OPERATIONS ASHORE; A HAND-BOOK FOR FIELD SERVICE, PREPARED FROM OFFICIAL AND STANDARD AUTHORITIES. By H. K. GILMAN, First Lieut. U. S. M. C. Naval Professional Papers, No. 20. 16mo, leather tuck.

In the May number we quoted, under "Publications Received," the titles of the Naval Professional Papers from No. 1 to 18, inclusive. The above title is that of No. 20 in this same series, No. 19, for some reason, not having made its appearance. The present volume is a nicely gotten up manual, bound in full leather, and evidently intended to be carried in the pocket as a reference book. It is mainly a compilation from various writers, giving in a concise form such military principles and general information as naval officers would naturally require when officiating ashore with an armed force. As the book is issued by the Navy Department, it is to be assumed that all the instruction and information given bears official sanction, and it is therefore quite superfluous to say that the book is a valuable one; for inasmuch as the work is a gathering together in a concise and compact form all the instructions required for officers of the Marine Corps, it is assumed at once that to them, at least, it is almost invaluable. We can say, however, that it might have been better printed, and the table of errata shows inexcusable carelessness in the proof reading.

STEAM-HEATING PROBLEMS; OR QUESTIONS, ANSWERS, AND DESCRIPTIONS RELATING TO STEAM-HEATING AND STEAM-FITTING. From *The Sanitary Engineer*. With one hundred and nine illustrations. New York: *The Sanitary Engineer*. 1886. 1 large 8vo volume, handsomely bound in cloth. Price, post paid, $3.00.

This volume of 233 pages, just out from the *Sanitary Engineer* press, cannot fail to find at once a large number of friends who have been vainly on the look out for an American book of this kind. The book is eminently serviceable to all those who design, construct, and have charge of steam-heating apparatus; but it will also prove useful to civil, mechanical, and sanitary engineers, to architects and to all manufacturers who own a steam boiler for power purposes. Incidentally, we notice a number of other questions come in for discussion, such as contrivances for raising water automatically in high buildings, heating water in large tanks, and for large institutions, coating water pipes, testing gas pipes, and methods of gas-fitting, probably because the ordinary steam-fitter or mechanic is frequently called upon to do such work, not strictly coming under the title "Steam-heating Problems." Again, we find questions on ventilation, on moisture on walls, etc ., on hot-water heating, discussed at length, we presume because questions of heating and ventilation are closely connected, and cannot always be treated separately, and because hot-water heating differs but little in arrangement from steam-heating.

The steam-heating problems presented are numerous, and the solutions and answers are of practical value, and often of great interest. The subjects discussed embrace steam boilers, calculation of heating surfaces, radiators and heaters, piping and filling, cutting nipples, bending pipes, steam, exhaust steam, superheating steam, and a large variety of questions under the headings "Miscellaneous" and "Miscellaneous Questions." The volume also contains illustrated descriptions of steam-heating plants in several large New York office-buildings, of warming and ventilating arrangements in several churches and theatres, etc.

The book is largely made up from the "Queries and Replies" which have formed a special feature of the volumes of the *Sanitary Engineer*. It forms a companion volume to the "Plumbing and House-Draining Problems" issued some time ago by the same publishers.

PHOTO-MICROGRAPHY. By I. H. JENNINGS. London: Piper & Carter.

This is one of the useful photographic handy books issued by the firm of Piper & Carter, and treats of a subject which has much to interest the scientific amateur who possesses a microscope and "dabbles" in photography. Photo-micrography is a very useful art, for, amongst other reasons, it enables a lecturer to exhibit in an enlarged form exactly what has been seen under the microscope. Mr. Jennings gives much valuable information in this handbook, and his remarks on microscopical apparatus generally will be very useful to the beginner. There are so many wretched specimens of workmanship in the market sold as microscopes by persons who are opticians only in name, that Mr. Jennings thinks it necessary to caution beginners who want a microscope for real work against purchasing an instrument from any "but an optician of reputation." That may be good advice; but the novice who is ignorant of the methods of testing a microscope, is not likely to be acquainted with the reputations of opticians, and he had much better obtain the services of a skilled microscopist in choosing his instruments—that is, where any large sum of money is to change hands. The best-known English firms all sell really good microscopes at a moderate figure now, and the beginner, even if his purse is a deep one, will act wisely by commencing operations with one of the lower-priced instruments. In his introduction, Mr. Jennings says that a

"photo-micrograph allows no room for play of the imagination; it simply shows how a given object appeared at the time the observation was made"; but we venture to think that a great deal depends on the skill of the operator, both as a microscopist and a photographer, for certainly all photo-micrographs do not impart the same appearance to identical objects. Mr Jennings means, of course, when the operator is skilled in both branches, and he explains at some length that to produce creditable photo-micrographs, it is necessary, first of all, to be a skillful microscopist; but being that he should also have had, not some, but a good deal of experience in photography. There is, however, no reason why anyone possessed of average intelligence should not become a first class producer of photo-micrographs, and amongst the ranks of what are called scientific workers there are many who stand in the front rank as photo-micrographers. Like most other arts, experience is required, for we learn more by failures than by successes; but, so far as a text-book can help, nothing better can be desired than this little work by Mr. Jennings, which contains a chapter on the methods of preparing bacteria by Dr. R. L. Maddox, M. D. It may interest readers to know that Mr. Jennings recommends rapid dry-plates for photo-micography, provided they are prepared with good, hard gelatine. His book is usefully illustrated, and will be found to contain all needful information.

ELECTRICAL TRANSMISSION OF ENERGY, AND ITS TRANSFORMATION, SUBDIVISION, AND DISTRIBUTION. By GISBERT KAPP, C. E. London: Whittaker & Co. (Second notice.)

The author of this book leads his readers so gradually from the consideration of elementary principles to the clear statement of the conditions of successful solution of the most important practical problems, that the treatise will be of great value to students who are not yet expert in electrical work.

The author's estimate of the magnitude of the general problem is expressed in his introductory chapter, which we herewith append:

"The transmission of energy and its transformation is the fundamental problem of mechanical engineering. No piece of mechanism yet devised is able to create energy, but all mechanism has for its object the transmission and transformation for useful purposes, of energy already existing in nature in a more or less inconvenient form. The more perfect our mechanical appliances, the better are they fitted to direct the forces of nature to do useful work; and in this sense the electric transmission of energy must be regarded simply as an improvement on purely mechanical methods already existing. But it is something more. It not only improves mechanical methods, but extends the field for their application, inasmuch as it can, in many instances, reach nearer to the sources of power than any mechanical means.

"The most important natural sources of power are fuel, wind and water. As regards the first-named, electrical transmission can hardly be considered of any great importance for the purpose of reaching the source of power, for fuel, especially in its most useful form of coal, is so easily portable, that in most cases it is more convenient to carry the fuel to the place where the energy is required than to transform it into energy where found and transport the energy to the place of application. It has been suggested to erect large generating stations for electricity close to the pit's mouth, and work the dynamos by steam power obtained from the small coal which is not worth being carried by rail. The current generated could then be sent along wires to neighboring towns, and thus the energy contained even in the refuse of our coal fields could be utilized. As yet, this suggestion has not been carried into practice, except on a very limited scale, namely, in providing motive power for underground railways in coal mines.

The other two great natural forces, wind and water, especially the latter, offer a larger field for the application of electricity. Water power is only portable in a very limited sense. The great cost of channels, and the difficulty of providing elevated reservoirs close to those places where the power would be of greatest use, compels us in most cases to establish our factories close to natural waterfalls; in other words, we cannot carry water power to the work, but we must take the work to where the water power is. Where that is impossible or inconvenient, the power cannot be directly utilized. It is in these cases that electrical transmission of power is of greatest value, inasmuch as it enables us to get at many sources of energy which would otherwise be wasted. The amount of energy contained in waterfalls all over the world is enormous. To cite only one or two cases. According to Herr Japing, the hourly weight of water falling in the Niagara is one hundred million tons, representing about sixteen million horse-power, and the total production of coal in the world would just about suffice to pump the water back again. M. Chretein, a French engineer, has, in a paper read at the Paris Electrical Exhibition in 1881, given the total water power in France as seventeen million horse-power, and has suggested that if by electric transmission only a part of this vast amount of energy were made available for useful purposes, an enormous economy in the consumption of fuel in France would be effected, and, at the same time, the hydraulic works necessary would also have the beneficial result of preventing, or at least mitigating droughts and inundations. This suggestion has already borne fruit, although only on a small scale. Near Bienne, in Switzerland, there is a waterfall representing an energy of several thousand horse-power. A small portion of this power is utilized by a turbine, which works a generating dynamo. The current is conveyed by an overhead line, consisting of a pair of copper wires (270 mills diameter) to Bienne, a distance of about a mile, where it works two electric motors; one in a mill where silver is rolled, and where the power required is very variable; the other in a watch factory, where, on account of the delicate nature of the work, an absolutely constant speed is required. The installation has now been at work with perfect success for over two years.

Another instance of electric transmission in connection with water power is the electric railway at Portrush, in Ireland, where the energy of a waterfall is, by means of a turbine and dynamo converted into electrical energy, which is conveyed to the line and along the rails into the motor of the car. There it is reconverted into mechanical energy, and utilized in propelling the car. Examples of this class might be multiplied, but these two will suffice to show that a practical beginning has already been made in the application of electricity for the purpose of reaching some sources of energy which would otherwise be lost. If progress in this direction has not been as fast as might be desired, the reason lies in this that installations of this kind are necessarily of some magnitude, and cannot be undertaken as mere experiments. If a small installation of electric lighting were to turn out a failure in any particular case, the loss to the contractor would not be so very serious. The dynamo, the wire and the lamps have all their fixed market value, and if they have to be removed from one installation, they can be utilized to another. Not so with the transmission of energy from some hitherto inaccessible source. The dynamo and the motor have to be built specially for each particular case, and the probability that they can be used elsewhere is small. The line and supports are expensive items, which have only value in that particular locality where they have been erected, and the works necessary for transforming the crude energy of nature so as to be applied for driving the generating dynamo have also only a local value. In such cases the installation must be a complete success, or else most of the plant and work is a dead loss; and it is but natural that capitalists shrink from rushing into enterprises as long as there is the least taint of an experimental nature about them.

Another reason which has, in England, at least, operated to delay the electric transmission of energy from natural and inaccessible sources to more convenient places, is that in this country coal is cheap and water power scarce. In France the case is different, and accordingly we find that the first experiments on a large scale have been undertaken there. Although it is quit incorrect to say, as is frequently stated in French papers, that M. Marcel Deprez has invented the electric transmission of energy, or has even invented any special system by which the electric transmission of energy is made practicable, it must be admitted that he has had the courage of his opinion, and has been the first to demonstrate that energy can be transmitted electrically over long distances. All scientists have long been agreed on the necessity of employing for long distance transmission currents of high electromotive force, but M. Marcel Deprez was the first to carry this into practice.

Broadly speaking, there are two purposes for which the electric transmission of energy is of great value. The one comprises all cases where, as has been shown above, hitherto inaccessible sources of natural energy are by its means rendered accessible, and the other comprises all those cases where the source of energy itself is accessible, but where it is desired to distribute it to a number of independent small working centers. In the first case we have to transmit a large amount of energy, so to speak, in one lump from the distant source to the place of operation; and, in the second case, we have to split up the energy of a source close at hand into a number of small fragments, and distribute them within a limited area to do useful work. In this case, electric transmission of energy comes into competition with the more mechanical means of belts, shafts, wire ropes, and pneumatic or hydraulic tubes, and the question whether one or the other of these systems is preferable, depends on the amount of energy transmitted, and the distance over which it is transmitted, as well as on many local circumstances. Electricity has the great advantage of being extremely portable, and capable of having its direction and intensity changed with greatest ease. No mechanical force can be detected in the conductor carrying the electrical energy such as appears during purely mechanical transmission with shafting, belts, wire ropes, or in pipes conveying steam, water or air. The conductor is clean, cold, does not move, and altogether appears inert. It can be bent, moved, or shifted in any manner, while transmitting many horsepower. It might be brought round sharp corners, and having little weight, it can be fixed with greater ease than any mechanical connection It is thus possible to bring the energy into rooms and places awkwardly situated for mechanical transmission, and there is no noise, smell, dirt, or heat during the transit, nothing to burst or give way. The power is, moreover, under perfect control, and its application exceedingly elastic. The same circuit which may be tapped to give many horse-power can, at the same time, and as conveniently, be used to work a sewing machine, or other small domestic implement, and the power consumed at the generating dynamo is always in proportion to the power obtained from all the motors, so that there is no waste of energy if some of the motors are standing still or are working with less than their full load. In addition to these advantages, electrical distribution of energy has also the merit of being exceedingly economical. The commercial efficiency of dynamos and electro-motors seldom falls below 80 per cent., and is in many cases as high as 90 per cent., so that even if we make a liberal allowance for loss of energy in the conducting wires, 60 per cent. of the power of the prime mover at the generating station can be recovered from the motors distributed over a limited area. For instance, a steam-engine of 100 horse-power, driving a generating dynamo in the center of a two-mile circuit, could deliver an aggregate of 60 horsepower in as many separate points within that circuit. Apart from all considerations of nuisance and cost of attendance in the case of sixty separate small steam-engines placed throughout the district, which might be used instead of the sixty elecro-motors, it is evident that we can generate one hundred horse-power in one single engine at a far less cost of fuel than could be done in small engines, and although the double conversion necessitated by electrical distribution of energy entails some loss, there

is still a large margin in the general economy of the system.

In some cases it is found convenient to transmit the energy from the generating dynamo, not directly to the motors, but to interpose between the two a set of accumulators or secondary batteries. This is, in reality, an extension of the system, and has the double advantage of providing motive power even at those times when the generating dynamo is standing still, and also of giving to the motor a certain amount of portability. Electric transmission of power is thus actually carried beyond the limits of a fixed conductor, or is even effected without the aid of a conductor at all. As a case in point, may be cited the propulsion of street tramcars by means of secondary batteries. Here we have a charging station at some place near the line containing some prime mover and dynamos, the current from which is sent by a pair of cables to the secondary batteries in the car which are to be charged. This is the first stage in the electric transmission of energy. When the cells are fully charged, the cables are detached, and the car is ready to start, and during its journey the second stage of the transmission, viz., that of the energy in the cells into the motor, takes place. By the employment of secondary batteries, we have thus carried the operation beyond the limits of the cables If the charging station is so situated that cars can enter it, the process of charging can be accelerated by making each set of cells detachable from the car, and charging them whilst the car, furnished with a duplicate set, is on the line. As each car comes in, its set of exhausted cells is replaced by a set newly charged, and can go out again within a few minutes. In this case the actual transmission of energy between the dynamo and the cells, which are placed in close proximity, is only over the space of a few yards; yet this energy may, later on, be utilized over a very long line.

A similar system is in use for the propulsion of small boats by electricity. It can be most conveniently applied in the case of launches belonging to vessels which are fitted with the electric light; for the same dynamo which works the incandescent lamps at night can be used to charge, or keep charged, the accumulators in the launch during the day time, so that the latter may at a moment's notice be lowered into the sea, provided with a sufficient store of energy for some hours' run. When the launch is stowed away on deck, its accumulators can also be used for lighting the vessel, if a mishap occurs to the dynamo, or if it be necessary to stop the machinery for some other reason.

Examples of this kind might be multiplied to any extent, but sufficient has been said to show that in the present state of electrical industry, the electrical transmission of energy is a question of great practical interest. Its application is not only confined to the transmission of power, pure and simple, between two distant points, as commonly understood, but it enters more or less into every application of electricity."

Besides the general exposition of the principles involved in the general solution of the great problem, some space is given to classification of existing motors and their work.

MISCELLANEOUS.

A NEW ELECTROTYPING SOLUTION.—Dr. Gore, F. R. S., the well known authority on electro-deposition, has discovered that an aqueous solution of asparagine is a good medium for electrolytic baths. The solution he used was not quite saturated, and consisted of about 88 gramme of crystals of asparagine dissolved in 18 cubic centimeters of distilled water. It was feebly acid to the test paper, and was employed at a temperature of about 70 deg Cent. Some of the liquid was more or less saturated with different metallic oxides, and the resulting baths electrolyzed by currents from one to six cells of zinc and platinum in dilute sulphuric acid. Good deposits of cadmium were thus obtained, .23 gramme of hydrate oxide of cadmium dissolved in 20 cubic centimeters of the solution, using an anode of cadmium and a cathode of copper. Zinc was deposited from .28 gramme of zinc oxide in 23 cubic centimeters of solution. Magnesium in a film was also deposited from calcined magnesia with magnesium and copper electrodes; copper was obtained from cupric oxide with copper and platinum electrodes; mercury from red mercurious oxide with platinum electrodes; and silver from oxide of silver with a silver anode and platinum cathode. In the latter case the deposit was good, the bath consisting of .33 gramme of silver oxide in 20 cubic centimeters of asparagine solution.

MAGNESIA IN PORTLAND CEMENT.—For a long time magnesia has been supposed to have a bad influence when present in cements, and M. Lechartier has been investigating the nature and cause of its action in structures built with cement, such as basins, dams, and retaining walls, either exposed to air or water. These structures were built by competent engineers in different localities. The cements used did not contain sulphate of lime in a harmful proportion, they had a proper density, and were made of good sands. Nevertheless in all cases the effects were the same, and a slow destruction of the cement went on with time. The explanation of the facts arrived at by M. Lechartier is that the cements employed were really mixtures of Portland cement with magnesia which behaved at first as an inert substance; but little by little the magnesia became hydrated, producing expansion of the mortar and the deterioration of the works. St. Clair Deville has shown that pure magnesia without admixture of silica and alumina can combine with water to form a hydrate of great hardness, but the formation is accompanied with increase of volume. Portland cement alone contains but a small proportion of magnesia. M. Lechartier further observes that the increase of volume of the mortars takes place more rapidly when the water gains access more readily to the mass. Hence the basins of fountains, reservoir walls, and so on, are affected in a comparatively short time.